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THE HERSILIIDAE (ARANEAE) OF SOUTH AFRICA.

By Reay H. N. Smithers, B.Sc., South African Museum, Cape Town.

(With Twelve Text-figures.)

(Read March 19, 1941.)

Of the four genera comprising the family *Hersiliidae*, i.e. *Tama*, *Hersilia*, *Hersiliola*, and *Murricia*, *Murricia* is the only genus not found in South Africa.

Up to the present the genus *Tama* has been represented in South Africa by one species: *Tama incerta* Tucker (2); *Hersilia* by six species : *H. bicornis* Tucker (2), *H. corticola* Lawrence (6), *H. sericea* Pocock (7), *H. pungwensis* Tucker (2), *H. arbores* Lawrence (3), and *H. setifrons* Lawrence (3); *Hersiliola* by two species: *H. australis* Simon (1) and *H. fragilis* Lawrence (3). To this list the following new species of the genus *Tama* are now added, *T. arida*, *T. bicava*, and *T. obscura*.

The three South African genera fall into two distinct groups, the first formed by the single genus *Hersilia*, the second by the genera *Tama* and *Hersiliola*. These two groups are readily distinguished one from the other in that the metatarsi of the first, second, and fourth legs of the first group are biarticulate, being provided with a false articulation about the middle of the metatarsi; whereas the second group have uniarticulate metatarsi, as in the great majority of spiders. Furthermore, the chelicerae of the first group are armed with a series of three large and several small teeth, whereas the chelicerae of the second group are unarmed (text-fig. 4).

The characters which have been used to distinguish the genus *Tama* from *Hersiliola* have, up to the present, proved confusing. Simon in his key to the genera (1) used the relative lengths of the legs and the relative lengths of the apical and basal joints of the superior spinerettes:—

"Pedes cuncti subsimiles, mamillae superiores articulo apicali basali haud vel vix longiore . . . . *Hersiliola*
Pedes valde inaequales. 3[1] reliquis multo breviores, mamillae superiores articulo 2° longissimo . . . . *Tama*."

Now, while the second of the two characters used by Simon appears to hold good for South African specimens of *Tama* and *Hersiliola*, the use of the first character is of doubtful value. In both genera the third leg is

shorter than the other three, but it is only when a series of specimens of the two genera are available for comparison that it can be seen that in *Tama* the third leg is shorter in comparison with the remainder than in *Hersiliola*. In dealing with small numbers of specimens, therefore, this character is open to conflicting interpretations.

Examination of material in the collections of the South African and the Natal Museums has shown, however, that there are other more sharply

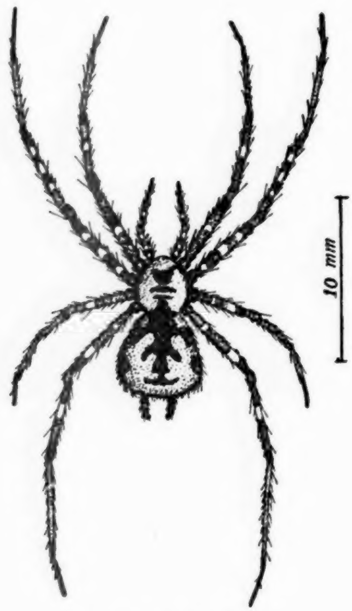


FIG. 1.—*Tama arida* n. sp.

defined characters of greater value in differentiating between the two genera. These additional characters, details of which follow, coupled with the second of the two characters used by Simon in his key, are incorporated in the new key to the genera given in this paper.

The curious plumose setae, which densely cover the abdomen and cephalothorax of all three genera of South African Hersiliid spiders, vary in colour from golden brown to pure white (text-fig. 2). The colours given for the species now described are taken from specimens bathed in spirit, thus allowing the pattern and ground colour of the specimen, which otherwise are obscured by these plumose setae, to be seen.

As has been pointed out by Dr. R. F. Lawrence in his ecological notes on the Arachnid Fauna of South West Africa (3), coloration varies greatly among specimens of the same species from different environments. He quotes *Hersilia arborea* in which specimens from the bright yellow bark of the Corkwood tree were of a bright yellow colour, whereas others from the dark slate-grey Baobab were melanic. This variation in colour was particularly noticeable during the present investigation in a series of *Hersilia setifrons* from Windhoek, South West Africa, which were almost jet black with but faint abdominal markings, while in Lawrence's types of

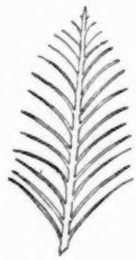


FIG. 2.—Plumose seta from the abdomen of *Tama arida* n. sp.

this species from the Kaokoveld the abdomens are predominantly yellowish brown.

A similar variation was found in a series of *Hersilia bicornis.*

As far as Tucker's *Hersilia pungwensis* is concerned, some doubt still exists as to whether the female collected near Umtali, Southern Rhodesia, is indeed the counterpart of the male used by him as the type of this species, which was collected some five miles south-east of this locality. This female is very similar to females of the species *Hersilia bicornis*, differing only in the relative sizes of the anterior and posterior median eyes. The palp of the male type of *Hersilia pungwensis*, however, differs in certain characters from the palps of the males of *Hersilia bicornis*, these differences being of sufficient significance to show that it is indeed a distinct species. Unfortunately, as Tucker himself points out, the specimens chosen by him as the types of *Hersilia pungwensis* are badly damaged; consequently it has not been possible to compare other characters with specimens of *Hersilia bicornis.*

I have to thank Dr. Lucien Berland of Paris for examining Simon's types of *Hersiliola australis* and supplying me with drawings and details; also Dr. R. F. Lawrence, Director of the Natal Museum, Pietermaritzburg, for the loan of specimens.

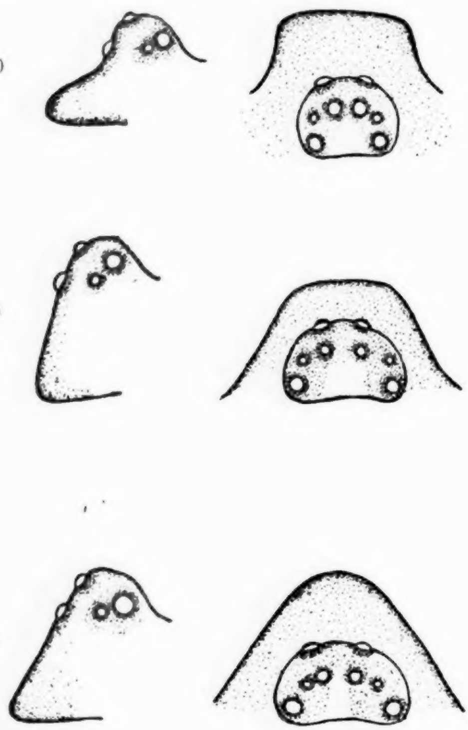
Unless otherwise stated specimen numbers refer to records of specimens in the collection of the South African Museum.

CAPE TOWN,
August 1939.

FAMILY HERSILIIDAE.

Key to the South African Genera of Hersiliidae.

1. Metatarsi uniarticulate, chelicerae unarmed. Clypeus anteriorly rounded (text-figs. 3, *b*, *c*) . . . . 2.
   Metatarsi (except metatarsi of third leg) biarticulate, chelicerae armed with three large and a series of about twelve minute teeth. Clypeus anteriorly truncate (text-fig. 3, *a*) . . . . *Hersilia.*



(*a*)

(*b*)

(*c*)

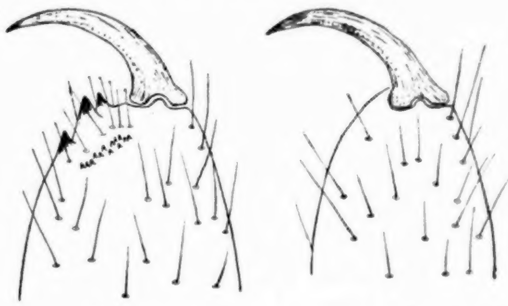
FIG. 3.—Lateral and dorsal views of the clypeus and ocular tubercle of (*a*) *Hersilia*, (*b*) *Hersiliola*, (*c*) *Tama*.

2. Apical joint of superior spinerettes one-third of its own length longer than the basal joint, and subequal to the length of the sternum. Tarsus of first leg greater than half the length of the metatarsus, anterior margin of clypeus with the lateral angles rounded, projecting but little beyond eye tubercle (text-fig. 3, *b*) . . *Hersiliola.*
   Apical joint of superior spinerettes subequal to twice the length of the basal, and greater than the length of the sternum. Tarsus of first leg subequal to or less than half the length of the metatarsus, anterior margin of clypeus bluntly triangular, projecting beyond eye tubercle (text-fig. 3, *c*) . . . . . . *Tama.*

Genus HERSILIA Audouin.

Aud. in Sav. Descr. Eg., 2nd ed., xxii, p. 317, 1825–27.

(Text-figs. 3, *a* and 4, *a*.)



(*a*). (*b*)

FIG. 4.—Chelicerae of (*a*) *Hersilia*, (*b*) *Hersiliola* and *Tama*.

Hersilia bicornis Tucker.

(Text-figs. 3, *b* and 6, *d*.)

Ann. S. Afr. Mus., vol. xvii, p. 473, pl. xxix, fig. 10, 1927.

♂ and ♀, B 864, Krantz Kloof, Natal; ♂ and 2 ♀♀, B 4225, Kaapmuiden, E. Transvaal; ♀, B 4334, Komatipoort, E. Transvaal.

Hersilia corticola Lawrence.

(Text-fig. 5, *d*.)

Ann. Nat. Mus., vol. viii, part 2, p. 226, text-fig. 7, p. 227, 1937.

2 ♀♀, Hluhlowe Game Reserve, Zululand.

Hersilia sericea Pocock.

(Text-fig. 5, *c*.)

A.M.N.H. (7), vol. ii, No. 9, p. 214, pl. viii, fig. 9, 1898.

2 ♀♀, British Museum 97. 2, 30, 43–47 Syntypes, Estcourt, Natal; ♀, Estcourt, Natal.

Hersilia pungwensis Tucker.

(Text-figs. 5, *e* and 6, *c*.)

Ann. S. Afr. Mus., vol. xvii, p. 475, pl. xxix, fig. 10, 1920.

♂, 13639, Pungwe River, 5 miles S.E. of Umtali, S. Rhodesia; ♀, 12509, Umtali, S. Rhodesia.

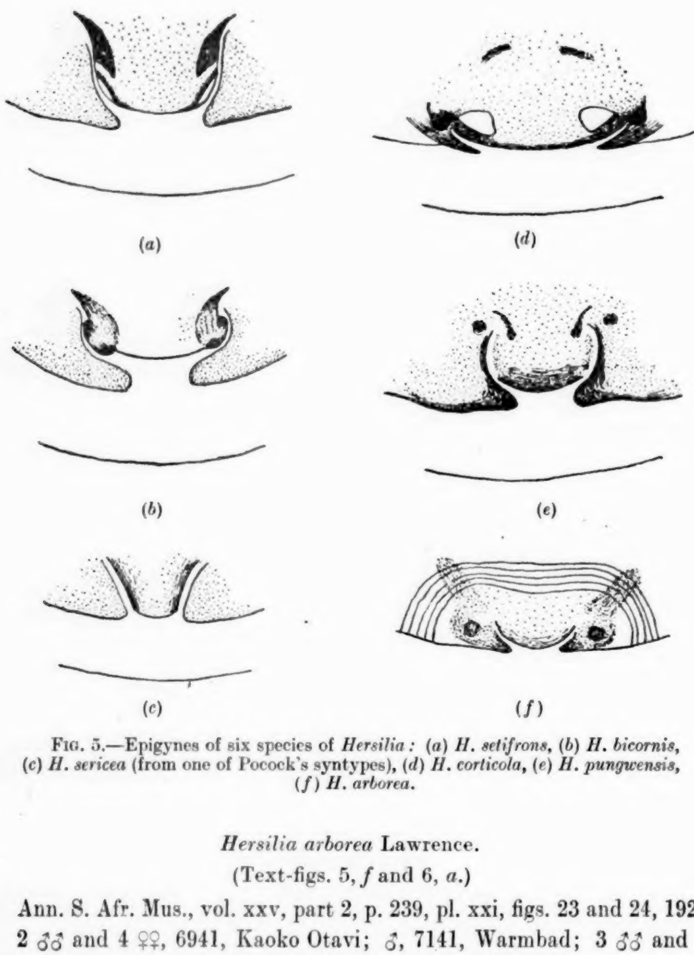


FIG. 5.—Epigynes of six species of *Hersilia*: (*a*) *H. setifrons*, (*b*) *H. bicornis*, (*c*) *H. sericea* (from one of Pocock's syntypes), (*d*) *H. corticola*, (*e*) *H. pungwensis*, (*f*) *H. arborea*.

Hersilia arborea Lawrence.

(Text-figs. 5, *f* and 6, *a*.)

Ann. S. Afr. Mus., vol. xxv, part 2, p. 239, pl. xxi, figs. 23 and 24, 1927.

2 ♂♂ and 4 ♀♀, 6941, Kaoko Otavi; ♂, 7141, Warmbad; 3 ♂♂ and ♀, 6944, Kaoko Otavi; ♂ and ♀, 6726, Outjo—all S.W. Africa.

Hersilia setifrons Lawrence.

(Text-figs. 5, *a* and 6, *b*.)

Ann. S. Afr. Mus., vol. xxv, part 2, p. 241, pl. xxi, fig. 25, 1927.

5 ♀♀ and ♂, 6665, Sesfontein; ♂, 7140, Kaoko Otavi; 2 ♀♀, 6653, Warmbad; 4 ♀♀ and 3 ♂♂, B 5183, Windhoek; 2 ♀♀, B 5502, Windhoek—all S.W. Africa.

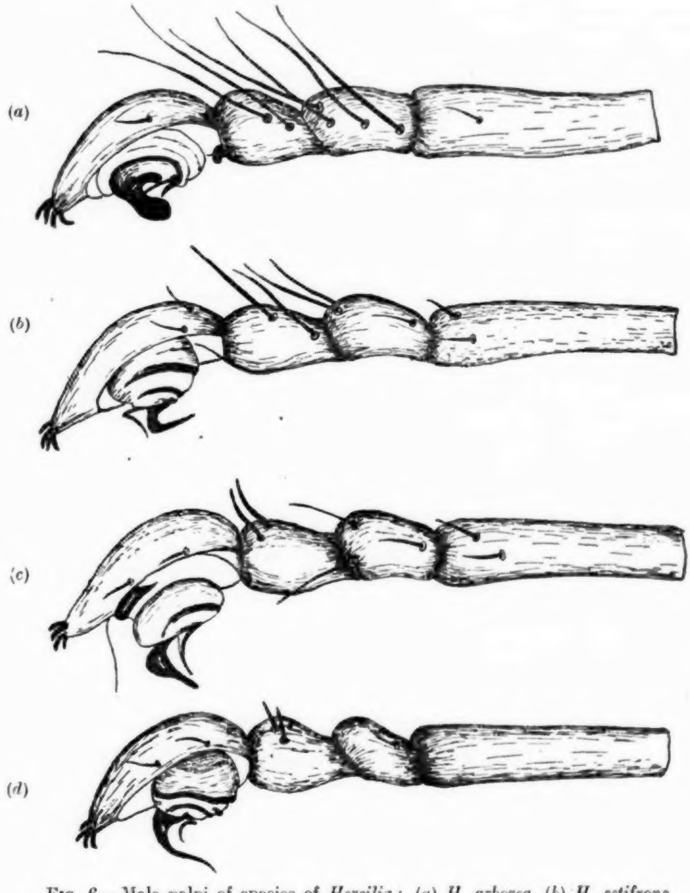


Fig. 6.—Male palpi of species of *Hersilia*: (*a*) *H. arborea*, (*b*) *H. setifrons*, (*c*) *H. pungwensis*, (*d*) *H. bicornis*. The femur and patella of Tucker's type *H. pungwensis* are missing, the figure of these two portions of the palp being reconstructed from his description.

Key to the Species of the Genus Hersilia.

FEMALES.

1. Length of clypeus less than length of median ocular quadrangle, clypeus not projecting much beyond eye tubercle, apical portion of superior spinerettes over twice as long as cephalothorax . . . . *corticola.*
   Length of clypeus greater than the length of the median ocular quadrangle, clypeus projecting beyond eye tubercle for a distance at least equal to, usually greater than, half the length of the median ocular quadrangle, apical portion of superior spinerettes less than twice as long as the cephalothorax . . . . 2.
2. Eye tubercle high and narrow, the height of the tubercle * twice its width,† and subequal to 1¾ times the width of the tubercle at the posterior lateral eyes . *arborea.*
   Eye tubercle squat, the height of the tubercle 1½ times or less the width of the tubercle at the posterior lateral eyes . . . . 3.
3. Apical width of the median vulval plate subequal to half the basal diameter of the inferior spinerettes . . . . *sericea.*
   Apical width of the median vulval plate subequal to the basal diameter of the inferior spinerettes . . . . 4.
4. Median vulval plate broadening apically into two chitinised lateral processes . 5.
   Median vulval plate without lateral chitinised processes. . . . . *setifrons.*
5. Diameter of anterior median eyes subequal to twice the diameter of the posterior median . . . . *bicornis.*
   Diameter of anterior median eyes subequal to or but slightly greater than the diameter of the posterior median . . . . *pungwensis.*

MALES.

1. Tibia of palp with 2 spines on the inner margin . . . . 2.
   Tibia of palp without spines on the inner margin . . . . 3.
2. Tibial spines short and stout, palpal process tapering gradually to a fine point. *bicornis.*
   Tibial spines long and tapering to a fine point, palpal process broad and flattened towards the apex which tapers abruptly to a point . . . . . *pungwensis.*
3. Patella of palp dorsally with a medial row of 4, the tibia with 2, very long fine setae subequal to or longer than tarsus, palpal process spatulate, embolus short stout *arborea.*
   Patella of palp dorsally with 3 setae, a short basal and 2 long apical, the tibia with 2 long setae, the long setae subequal to ¾ length of tarsus, palpal process tapering to a point, embolus fine. . . . . *setifrons.*

Genus TAMA Simon.

Ann. Mus. Civ. Gen., vol. xviii, p. 295, 1882.

(Text-figs. 3, *c* and 4, *b*.)

Spiders of the genus *Tama* are found under stones or flat slabs of rock on the dry slopes of koppies in the arid parts of South Africa, the nests being attached to the under side of these stones.

* Measured from the level of the anterior edge of clypeus.

† Measured at the height of the median anterior eyes.

The nest consists of a circular wall of closely woven webbing in which small stone chips and particles of dry vegetable debris are incorporated. The outside of this wall is concave and smooth, the spider usually being found resting against this. Inside the circular wall there is a mass of fine strands of web and small stone chips. Around the circular wall, on the outside, hangs an irregular mass of fine webbing in festoons in which accumulate small particles of loose material. From the shelter of the nesting stone runs a fine openwork non-sticky mat-like web, lying close to the ground and extending for a distance of about nine inches to a foot, attached at vantage points to stones or other objects on the ground around.

The spider relies mainly on its speed of foot to catch its prey which is carried bodily to the shelter of the nesting stone to be devoured. The speed with which the act of capture on the webbing outside the nesting stone and the return to its shelter is accomplished is little short of amazing and, at times, is difficult to follow with the eye. The spider is almost as quick on the ground, and when examining suspected nesting stones, unless they are turned over with great caution, the spider immediately retreats at speed from the nest to the under surface of the stone and will try to retain its position on the under surface as the stone is rotated. At first this leads the collector to suppose that the nests which he is finding are deserted until he learns either to turn over the stone very carefully or, if possible, to lift it bodily from the ground and examine the under surface without rotating it.

The flattened hemispherical egg sacs are constructed close to the nest attached to the under surface of the stone in irregular heaps and covered with stone chips.

The males construct webs and nests similar to the females under neighbouring stones.

Tama incerta Tucker.

Ann. S. Afr. Mus., vol. xvii, part v, p. 476, 1920.

(Text-fig. 7, *a*.)

♀, 4298, Nieuwoudtville; 7 ♀♀ and Imm. ♂, B 1633, Beaufort West; 2 Imm. ♀♀, 3938, Beaufort West; 2 ♀♀, 14250, Touws River; ♀ and Imm. ♂, B 2467, Matjesfontein; 2 Imm. ♀♀ and Imm. ♂, 12862, Laingsburg; ♀, 13698, Prince Albert; ♀, 3640, Clanwilliam; 5 ♀♀ and ♂, Nauchaspoort; 4 ♀♀ and ♂, Montagu; 2 ♀♀, B 3028, Matroosberg, Ceres (3500–4000 ft.); 11 ♀♀, 12871, Matjesfontein; 7 ♀♀, B 7436, Prince Albert—all Cape Province.

Specific characters within the genus *Tama* are, on the whole, not well defined and, with the exception of the species *T. incerta*, very few specimens are available. In the provisional key given the relative sizes of the eyes are used as specific characters in differentiating between the four species,

but it is suggested, that at some future date, when further specimens are available, this may require modification. Confirmation of the fact that the species detailed are sound, however, is found in the structure of the epigynes, which differ noticeably throughout the series and form the most valuable aid in differentiating between them.

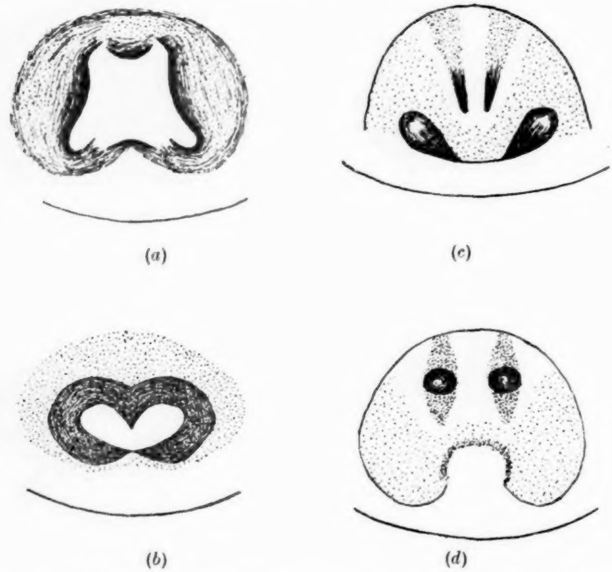


FIG. 7.—Epigynes of four species of *Tama*: (*a*) *T. incerta*, (*b*) *T. arida* n. sp., (*c*) *T. obscura* n. sp., (*d*) *T. bicava* n. sp.

Tama arida n. sp.

(Text-figs. 1, 2, 7, *b* and 8.)

Type, ♀ with egg sacs from Nauchaspoort, dist. Montagu, Cape Province, collected by R. Smithers, 1st June 1938. S.A.M. 9298.

FEMALE.

Cephalothorax.—Slightly broader than long in the proportions 7 : 6·5, dark yellow brown, margins, clypeus, and ocular area infuscated, with a broad black band from the median fovea to the basal margin, broadening basally. Sparsely covered with short fine setae, these more numerous on the anterior face of the clypeus.

Eyes.—Anterior median $\frac{3}{4}$ their diameter apart and the same distance

from the posterior medians. Anterior medians twice the diameter of the posterior medians which are their own diameter apart. Posterior medians $1\frac{1}{2}$ times their diameter from the posterior laterals and $1\frac{1}{2}$ times the diameter of the posterior laterals. Anterior laterals the smallest of the eyes, these nearer to the posterior laterals than to the anterior medians. Anterior width of median ocular quadrangle subequal to the length and slightly broader than the posterior width. Clypeus twice length of median ocular quadrangle (text-fig. 3, *c*).

Chelicerae.—Unarmed, subequal to $1\frac{1}{4}$ times the length of the clypeus.

Sternum.—Slightly longer than broad, light yellow, with a small black patch medially towards the anterior margin. Sparsely covered with long fine setae and margined with a dense fringe of white setae.

Abdomen.—Dull dark yellow brown, with an indented, infuscated, median longitudinal band for about half the length of the abdomen on the dorsal surface (text-fig. 1). Densely covered with short fine setae and sparsely with long fine setae. Ventral surface light yellow, covered with fine setae of medium and uniform length. Inferior spinerettes dark brown, apical portion of superior spinerettes $2\frac{1}{2}$ times length of basal portion.

Legs.—IV, II, I, III: dark yellow brown, femora III and IV with a subapical white or light yellow encircling band.

Epigyne.—Text-fig. 7, *b*.

Dimensions.—Cephalothorax, 5 mm.; abdomen, 3·5 mm.; leg IV, 19 mm.; leg II, 17 mm.; leg I, 15 mm.; leg III, 10 mm.

Collected under a flat stone on a rocky kopje. The egg sacs, six in number, were congregated in a heap, the whole covered with small stone chips. Four of the sacs were empty, one contained hatching eggs and from the remaining one young spiders were emerging.

Male.

Type ♂ from Nauchaspoort, district Montagu, Cape Province, 26th November 1938. S.A.M. No. 9578.

Cephalothorax.—Light yellow, margins narrowly infuscated, median fovea a transverse depression, black, and from this to the basal margin a black band broadening basally. Ocular tubercle black with a median line of four stout bristles. Sparsely covered with short fine setae.

Eyes.—As in the female.

Sternum.—Uniform light yellow, sparsely covered with long fine black setae, with a marginal fringe and a brush of light yellow setae on the posterior extremity.

Abdomen.—As in the female. Posterior pair of spinerettes light yellow, apical joint of anterior pair equal in length to sternum + labium, light brown with a black spot on the external surface basally. Basal joint of

anterior pair light yellow with a black spot corresponding in position to the black spot on the apical joint.

Legs.—IV, II, I, III: dark yellow brown. Femora III and IV with median black encircling bands and black towards their apices.

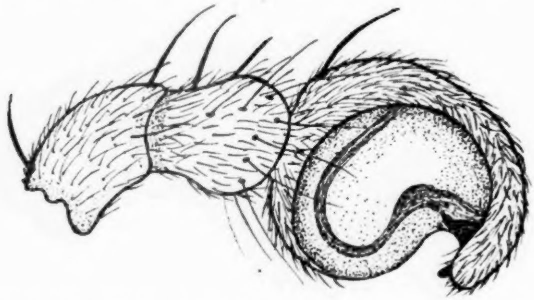


FIG. 8.—Exterior lateral view of R.H. male palp of *Tama arida* n. sp.

Dimensions.—Cephalothorax, 4 mm.; abdomen, 4·5 mm.; leg IV, 23 mm.; leg II, 19 mm.; leg I, 20 mm.; leg III, 11 mm.

Palpi.—As in text-fig. 8.

Specimens are also recorded from the following localities:—

2 ♂♂, B 3471, Matroosberg, Ceres, Cape Province, November 1917; 2 ♀♀, 9740, Williston, Cape Province, March 1939.

Tama obscura n. sp.

(Text-figs. 7, *c* and 9, *a*.)

Type ♀ from Matroosberg, Ceres, Cape Province, collected by R. M. Lightfoot, December 1917. S.A.M. B 3552.

FEMALE.

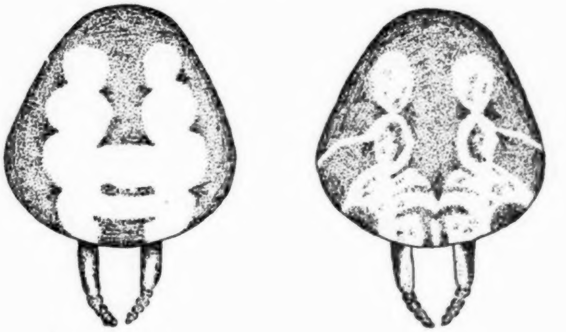
Cephalothorax.—As broad as long, brownish yellow, ocular area infuscated, a broad black band from the median fovea to the basal margin broadening basally. Margin narrowly infuscated, an infuscated patch on either side of the basal margin. With a marginal fringe of short setae, the ocular area sparsely covered with similar setae, in addition to which there are two very long fine setae, one in the median line immediately posterior to the posterior pair of eyes, the other in similar relation to the anterior median. Clypeus infuscated.

Eyes.—Anterior medians a diameter apart and ¾ their diameter from the posterior medians. Anterior medians twice the diameter of the posterior medians which are a diameter apart. Posterior medians 3 times their

diameter apart, the posterior laterals twice the diameter of the posterior medians. Anterior laterals the smallest of the eyes, these nearer to the posterior laterals than to the anterior medians. Anterior width of median ocular quadrangle greater than its length or its posterior width. Clypeus $1\frac{1}{2}$ times length of median ocular quadrangle.

Chelicerae.—Unarmed, subequal to length of clypeus.

Sternum.—As long as broad, light yellow, sparsely covered with dark brown long fine setae and densely fringed with long fine white setae.



(*a*) (*b*)

FIG. 9.—Dorsal abdominal pattern of (*a*) *Tama obscura* n. sp., (*b*) *Tama bicava* n. sp.

Abdomen.—Dull dark yellow brown with a median longitudinal crenulated black band dorsally and laterally with a crenulated black pattern as in text-fig. 9, *a*. Ventrally light yellow. Dorsal surface sparsely covered with short fine and long fine setae, ventral surface with fine setae of medium and even length. Apical joint of superior spinerettes twice length of basal joint.

Legs.—IV, I, II, III: femora, tibiae, and patellae dark brown, the femora and tibiae with a subapical and subbasal encircling narrow white or light yellow band. Metatarsi basally dark brown with a narrow subbasal encircling light yellow band, apically light brown. Tarsi light brown.

Epigyne.—As in text-fig. 7, *c*.

Dimensions.—Cephalothorax, 4 mm.; abdomen, 5·5 mm.; leg IV, 16 mm.; leg II, 14 mm.; leg I, 12 mm.; leg III, 9 mm.

The structure of the epigyne of this species differs from the epigyne of *Tama arida*.

Specimens are also recorded from the following locality:—

♀ and Imm. ♂, 7317, Touws River, Cape Province.

Tama bicava n. sp.

(Text-figs. 7, *d* and 9, *b*.)

Type ♀ from Kaoko Otavi, South West Africa, collected by Dr. R. F. Lawrence, January–April 1926. S.A.M. B 6940.

FEMALE.

Cephalothorax.—Dark brown, margins infuscated, median fovea a black transverse depression and from the centre of this to the basal margin a black band broadening posteriorly. Ocular tubercle with a row of long stout bristles medially, the ocular area infuscated.

Eyes.—Anterior medians ½ a diameter apart and slightly less than ½ their diameter from the posterior medians. Anterior medians twice the diameter of the posterior medians which are slightly less than a diameter apart. Posterior medians 1½ times their diameter from the posterior laterals which are 1½ times the diameter of the posterior medians. Anterior laterals the smallest of the eyes and nearer to the posterior laterals than to the anterior medians. Anterior width of median ocular quadrangle greater than its length or its posterior width. Clypeus 1½ times the length of the median ocular quadrangle.

Chelicerae.—Unarmed, subequal to 1¼ times the length of the clypeus.

Sternum.—Slightly broader than long, light yellow with an indistinct fuscous patch in the middle near the anterior end. Sparsely covered with long fine setae.

Abdomen.—Dorsal surface whitish, mottled with black, a distinct irregular median longitudinal black band from the basal margin for about three-quarters the length of the abdomen, laterally with a crenulated black pattern as in text-fig. 9, *b*. Dorsal surface densely covered with long fine setae and short fine setae. Ventral surface light yellow, covered with fine setae of uniform length. Inferior spinerettes dark brown, apical joint of superior pair light yellow with a basal black dark brown patch on the external surface. Apical joint just over twice length of basal joint.

Legs.—IV, I, II, III: dark brown, femora with subapical encircling white or light yellow narrow band. Tibia of leg IV with a similar band near its apex and another at about a fourth of its length from the apex.

Epigyne.—As is text-fig. 7, *d*.

Dimensions.—Cephalothorax, 2·5 mm.; abdomen, 3·5 mm.; leg IV, 10 mm.; leg III, 10 mm.

There is a further ♀ specimen in the collection of the South African Museum listed under the same number and from the same locality as the type.

Key to the Species of Tama.

FEMALES.

1. Epigyne a single aperture surrounded by a chitinous rim . . . . . . 2.
   Epigyne two distinct apertures . . . . 3.
2. Anterior median eyes at least a diameter apart, anterior width of median ocular quadrangle greater than its length . . . . *incerta.*
   Anterior median eyes less than a diameter apart, anterior width of median ocular quadrangle subequal to its length . . . . *arida.*
3. Anterior median eyes half their diameter apart, posterior lateral $1\frac{1}{2}$ times the diameter of the posterior median . . . . *bicava.*
   Anterior median eyes a diameter apart, posterior lateral twice the diameter of the posterior median . . . . *obscura.*

Genus HERSILIOLA Thorell.

European Spiders, p. 115, 1869–1870.

(Text-figs. 3, *b* and 4, *b*.)

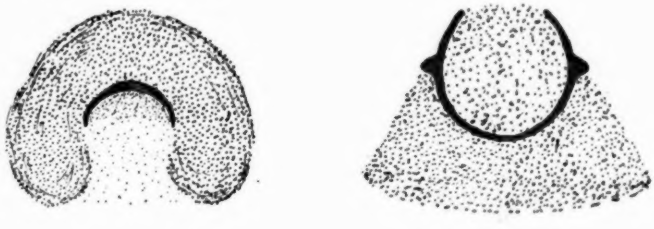
Hersiliola australis Simon.

(Text-figs. 11, 12.)

Hist. Nat. des Araignées, Tome Premier, p. 447, 1892–1895.

= *Hersilidia lucasii* Rev. O. P. Cambridge, P.Z.S., p. 562, 1876.

Unfortunately Eugene Simon's description of this species, given as a footnote in his "Histoire Naturelle des Araignées," is vague and no figure accompanies its description. Furthermore, his type locality is not precise, being given as "Africa-australis." I am inclined, however, to agree with Tucker (2) that all the specimens in the collection of the South African



(*a*) (*b*)

FIG. 10.—Epigynes of species of *Hersiliola*: (*a*) *H. australis*, (*b*) *H. fragilis*.

Museum enumerated in the following list are referable to Simon's species *Hersiliola australis*, in spite of the fact that some variation exists in the dorsal abdominal pattern.

Simon's description reads as follows: "Plaga vulva nigra, subrotunda, ciliata, foveola parva et rotunda impressa." Now while there always

remains some doubt when an attempt is made to correlate a complicated structure such as the vulva with a written description, Dr. L. Berland of Paris has been good enough to furnish me with a drawing of the epigyne of a specimen of this species identified by Simon. This shows clearly that the structure of this organ in Simon's specimen and in the specimens listed below are identical, although in the majority of cases under review the central chitinous ridge is more pronounced than in Simon's specimen. This is, however, probably due to fading of the colour with age, which fading is noticeable in one or two of the older specimens in the South African Museum collection.

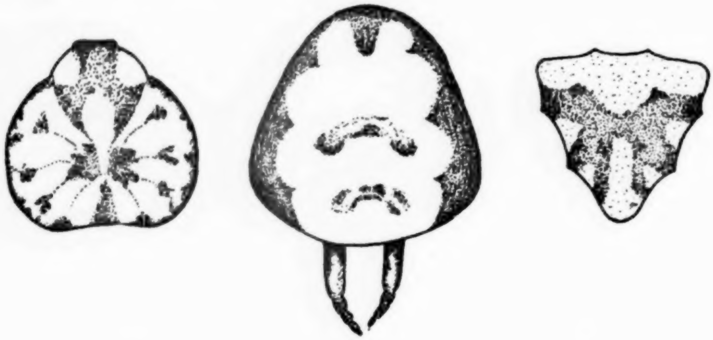


Fig. 11.—*Hersiliola australis*: (*a*) cephalothorax, (*b*) abdomen, (*c*) sternum—to show colour pattern.

Owing to the meagre description given by Simon, several important additional characters, useful in identifying the female of this species are given together with further details of the male first described by Tucker (2), the palp of which is drawn in fuller detail than given by him.

Hersiliola australis Simon.

♂ and 2 ♀♀ from Poortjesfontein, dist. Hanover, Cape Province, collected by Neeser, jun., 1905. S.A.M. 14481.

FEMALE.

Cephalothorax.—Light yellow, margins infuscated, with an irregular fuscous pattern in the region of the median fovea as in text-fig. 8, *a*. Sparsely covered with short fine setae, these more numerous on the anterior edge of the clypeus and in the region of the eyes. Ocular area infuscated, the whole densely covered with white and golden feather-like setae.

Eyes.—Anterior medians their own diameter apart and about ½ their

diameter from the posterior median, these $\frac{2}{3}$ the diameter of anterior medians, their own diameter apart, and $1\frac{1}{4}$ times their diameter from the posterior latèrals which are subequal to the anterior medians. Anterior laterals the smallest of the eyes and nearer to the posterior laterals than to the anterior medians. Clypeus twice length of the median ocular quadrangle.

Chelicerae.—Unarmed, subequal to length of clypeus.

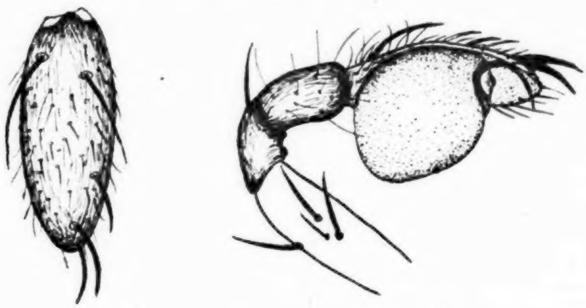
Sternum.—Slightly broader than long, light yellow with an irregular fuscous pattern as in text-fig. 11, *c*, sparsely covered with long fine setae forming a marginal fringe and a brush on the basal truncate extremity.

Abdomen.—Dull yellow brown with a crenulated black pattern on the sides as in text-fig. 11, *b*, covered with long fine setae and short fine setae and densely covered with white and golden feather-like setae. Posterior pair of spinerettes dark brown, apical joint of superior pair light yellow, equal in length to sternum, tapering to a fine point.

Legs.—IV, II, I, III: femora of legs I and II with three indistinct black encircling bands, one median and one at the junctions with the trochanter and patellae respectively. Legs III and IV with similar but very distinct bands.

Epigyne.—As in text-fig. 10, *a*.

Dimensions.—Cephalothorax + abdomen 6 mm.



(*a*) (*b*)

Fig. 12.—Male palp of *Hersiliola australis*: (*a*) Dorsal view of tarsus, (*b*) exterior lateral view of R.H. palp.

Male.

Cephalothorax.—Broader than long, rounded, light yellow, margins narrowly infuscated, with an infuscated pattern similar to that of the female.

Eyes.—Anterior medians their own diameter apart and about $\frac{1}{2}$ their diameter from the posterior medians, these $\frac{2}{3}$ diameter of anterior medians,

½ their own diameter apart, and twice their own diameter from the anterior laterals which are subequal to the anterior medians. Anterior laterals the smallest of the eyes and nearer to the posterior laterals than to the anterior medians. Clypeus twice length of the median ocular quadrangle.

Chelicerae.—Slightly longer than clypeus, unarmed.

Sternum.—Slightly broader than long, uniform light yellow, sparsely covered with long fine setae.

Abdomen.—Elongate oval, broader towards the apex, basally truncate, with a fuscous pattern similar to that of the female but more sharply defined. Covered with long fine and short fine setae.

Legs.—IV, II, I, III: metatarsi of third legs curved, concave dorsally, tarsi of fourth legs curved, concave ventrally.

Palpi.—Yellow, tarsus with a series of five bristles as in text-fig. 12. Patella with one large bristle on the dorsal apex and a second and smaller bristle on the promargin. Femur with one dorsal and a series of two large and one short bristle on the subapical promargin.

The South African Museum collection has specimens from the following localities:—

♀, B 4754, Montagu; ♀, 908, Mossel Bay; ♀, 3471, Matroosberg; Imm. ♂, ♀, 1180, Hanover; ♀, 11937, Hanover; ♀, 14481, Hanover; ♀, B 2987, Matroosberg, Ceres; 2 ♀♀, 8763, Colesberg; Imm. ♀, 3937, Beaufort West; ♀, 3361, Ashton; ♀, 3350, Robertson; 2 ♀♀, 12655, Montagu Baths—all Cape Province. ♀, B 7564, Vryburg, Bechuanaland.

Hersiliola fragilis Lawrence.

(Text-fig. 10, *b.*)

Ann. S. Afr. Mus., vol. xxv, part 2, p. 242, fig. 26, 1928.

2 ♀♀, B 7059, Outjo, South West Africa (Type); ♀, B 6729, Outjo; ♀, B 6745, Kaross; ♀, B 6663, Sesfontein; ♀, B 6188, Kunene River; ♀, B 2064, Usib River—all S.W. Africa.

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A KENYA FAURESMITH FACTORY AND HOME SITE AT GONDAR, NORTHERN ABYSSINIA.*

By J. Desmond Clark, M.A.(Cantab.).

(With three Text-figures.)

(Read August 11, 1943.)

The following brief account of a site of the East African Fauresmith culture, discovered during the final engagement of the Abyssinian campaign, is the result of a somewhat hurried examination on the 26th of November 1941 of a surface site on the edge of the Debat-Gondar plateau at an average altitude of 8400 feet. The time at my disposal was essentially limited, and was cut to just under an hour between the time when our own final military preparations had been made, and that at which we moved down to our positions in the broken country below for the assault upon Gondar itself. Implements and factory debris were lying on bed rock immediately below the surface and were particularly numerous. As representative a collection as possible was made, placed in a sack, thrown on one of the lorries and subsequently made its way to Gondar by another route after the town had fallen: this rather rough handling has resulted in the chipping of several of the implements.

The situation of the site, which can be seen from the sketch map, fig. 1, is on the edge of the Gondar-Debat plateau about sixteen miles from Gondar itself, which could be clearly seen from this position. The plateau, which is gently undulating, falls steeply on all sides except on the south-west, where it slopes more gently to the level of Lake Tana (2). It is possible that it may represent the remnant of an old erosion surface that has been subsequently upthrust during some period of volcanic activity before the formation of the present lake, which, according to Nilsson, owed its origin to damming by lava flows during the last inter-pluvial period (1). No sediments earlier than the Upper Pleistocene were found by Nilsson in this lake basin and, for myself, I was only able to distinguish two distinct terraces near lake level at Gorgora at the northern end of the lake. The

* The word "Kenya," introduced into the title in accordance with the terminology agreed on between the leading authorities, obtains full support from the author's text, the term "Kenya Fauresmith" being used in lieu of and as a substitute for "Nanyukian." —Editor.

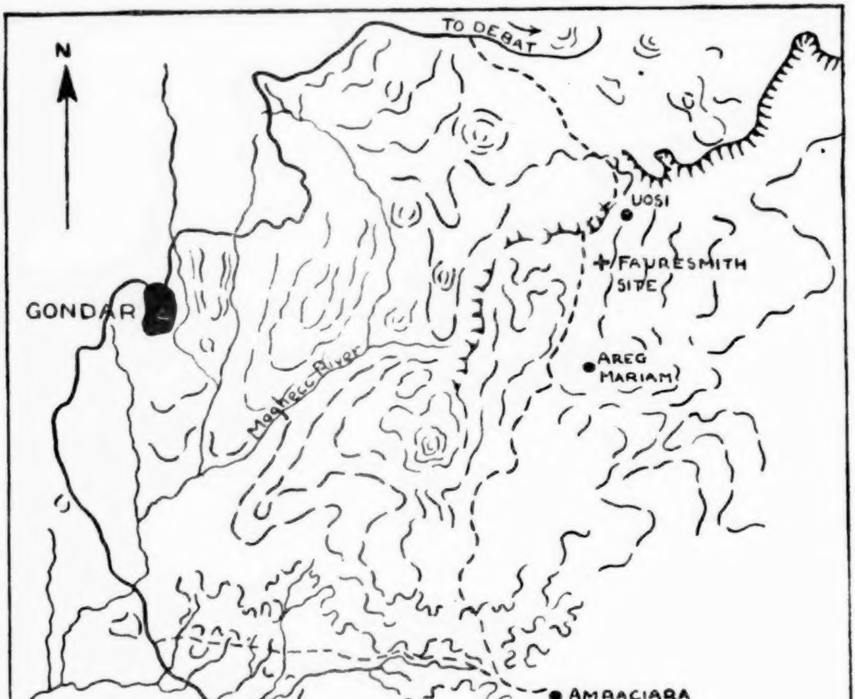
N
TO DEBAT
UOSI
+ FAURESMITH SITE
GONDAR
AREG MARIAM
Maghecc River
AMBACIARA
MILES
0 4 8 12
LAKE TANA
TO DEBRA TABOR

Fig. 1.

country between the Debat plateau, through Gondar, to the lake is very rough and dissected by streams and rivers deeply entrenched. On the plateau at the site in question were seen sparsely scattered but well-rolled pebbles of chalcedony or chert about 1½ to 3 inches in diameter, polished, patinated and with typical percussion and abrasion marks clearly seen. One doubtful "eolithic" implement was recovered, which had been well rolled, and may be contemporaneous with the pebbles. This implement, which is made from a brown chalcedony, shows a dark chestnut patina and is considerably abraded, all edges having been worn smooth. In shape it is roughly subtriangular, showing one distinct concave edge with working and similar work round the remaining sides. I at first considered that this implement and the pebbles were glacial erratics that had been washed into their present position from a terminal moraine. Nilsson noted fresh-looking moraines on mountains in the Semien, on the eastern side of the plateau, and south-east of Addis Ababa at heights under 10,000 feet (1). The question of the origin of the chalcedony, and whether the pebbles and implement are glacial erratics or provide evidence of a definite erosion cycle, is left entirely open, there being no conclusive evidence; certainly none of the pebbles showed typical glacial scratching; but how little of the material from glacial deposits does!

The factory site itself is later in date than the above implement as, although the material, always lava, is usually greatly weathered, it shows no evidence of abrasion by water action. The implements and debris are found in a surface accumulation of loam, usually yellowish brown but turning to black, with the addition of humic matter, at the surface. This deposit is almost certainly the result of disintegration and weathering of the underlying rock, a fine-grained lava, apparently a basalt; depth varies from a few inches to as much as 5 feet in one place, but for the most part the contour of the loam appears to follow that of the underlying rock with occasional pockets such as the above. In the deeper sections of this loam the colour changes to dark brown or red with numerous basalt "pebbles" and fragments of weathered rock spread throughout. Some kunkar nodules were also noted and presumably argue for drier conditions during formation than those pertaining there to-day. The implements, which are very numerous, are less weathered, as is natural, towards the base of the deposit. They occur on the surface and in the banks of a small rainwater gully. There is some evidence to suggest that the land was at one time under cultivation on the lynchet system so universal in this part of Abyssinia, while in places a scattering of Late Middle Stone Age flakes, quite fresh and made from silcrete and chalcedony, can be picked up. The Fauresmith industry appears to be confined to the plateau, as in the broken country between it and Gondar, in the valley of the Maghecc River

for example, there is no evidence of this industry. This deeply entrenched river shows evidence of one major and one minor period of erosion, previous to the present cycle, followed by aggradations, of varying thickness, of typical torrent-bedded material. Owing to lack of stratigraphy we have little corroborative geological evidence for dating this industry. Its position at a height of 8400 feet is perhaps of interest, as in Kenya Dr. L. S. B. Leakey first found sites of this culture at Nanyuki at a height of between 7000 and 8000 feet and suggested that its occurrence here might be due to the universal onset of arid conditions in East Africa, the water supply being found in abundance only at higher altitudes. This surmise was subsequently proved correct when he found this culture in stratified lake deposits laid down during the declining period of the Kamasian Pluvial at the onset of the succeeding long, arid Inter-pluvial (3). As the industry from Gondar differs in no marked way from the Kenya Fauresmith and in view of its position, at a high altitude only and apparently ante-dating the last period of major erosion, we may perhaps infer that it is of the same age, that is to say can be assigned to the very end of the Kamasian Pluvial and stretching into the succeeding arid Inter-pluvial.

To pass now to a description of the industry itself. The material employed is without exception a fine-grained basalt, which, although not a very satisfactory medium for the production of stone implements, yet shows that some very fine examples can sometimes be made from this rock. Owing to its unfortunate propensity for weathering, most of the implements and factory debris all show this to a greater or lesser extent, those from the surface being so weathered that all evidence of their human origin except their shape has been lost. Others are fortunately better preserved, so that from them it is possible to determine the technique employed in their production.

In all nintey-six implements, flakes, etc., were brought back, and below in tabular form can be seen the list of tool types: the numbers indicate roughly the degree of frequency with which the types were found to occur on the site.

TOOL TYPES OF THE GONDAR FAURESMITH INDUSTRY.

Handaxes.			Cleavers.	Choppers.	Side Scrapers.	Discs (Cores).	Flake Tools.	Flakes.		Prep. Core, large.	Stone Ball.	Total.
Pointed.	Limande.	Sub-T'glr.						Prep. Ptfm.	Unprep. Ptfm.			
28	4	3	9	8	8	3	9	7	15	1	1	96

Handaxes.—These are of two kinds, large (19), and small or diminutive forms of the first (16). In actual form they vary between the pointed or pear-shaped, fig. 2, Nos. 1–3 and 7, which is here that most usually met with, the limande merging into the elongated ovate, fig. 2, Nos. 4–6, and the subtriangular variety which tends to the cordiform, fig. 2, 9–10. They are made either from cores or, more usually, from flakes, the limande and subtriangular forms being invariably made from the latter. These flakes have usually been struck from unprepared cores, but some have been removed from large cores of the prepared type. Platforms have with one exception all been removed, this one showing a plain unfaceted butt. Fig. 3, No. 5, shows a handaxe in process of production from what appears to be a crudely prepared flake. The finished specimens show well-directed, thin, controlled flaking of a resolved nature; edges are straight and butts are carefully rounded. Sections are universally thin, lenticular or plano-convex. Unfinished specimens or roughouts are crude in appearance, thick in section with intersecting flake scars, showing in fact typical Abbeville or stone technique.

Cleavers.—Without exception are made either from end or side flakes. The commonest form is the U-shaped cleaver, fig. 2, No. 8, some showing gently converging sides towards the cutting edge. One very fine example shows a flared end at the cleaver edge—this has been made on an end flake, fig. 2, No. 11. Other examples show a pointed butt (two specimens only). Sections usually show a greater or lesser degree of biconvexity, but two specimens, which I take to be unfinished examples, show parallelogram cross-section. Trimming has usually been directed from both edges and round the butt, usually from the flake surface and the upper surface as well.

Choppers.—Under this term have been grouped certain core tools the use of which is uncertain: it is possible that some are roughouts for *coup de poing*. All are thick sectioned, usually biconvex, though some have been made from flakes. They vary from limande to elongated ovate in form and are similar in that they show either one or two cutting edges formed by typical stone technique.

Side Scrapers.—These are dealt with separately from the other flake tools as they are for the most part large and seem to show a definite tool type, whereas the other flake tools are rather aberrant in form. In shape they approximate to an elongated ovate. They are all made from side flakes with in every case the bulb and platform removed by secondary trimming from the upper surface of the tool. The scraper edge, which is convex, is formed on the opposite side of the tool to the bulb, and the trimming around the perimeter is executed from the flake surface. These implements are roughly a parallelogram in section, but very much flatter

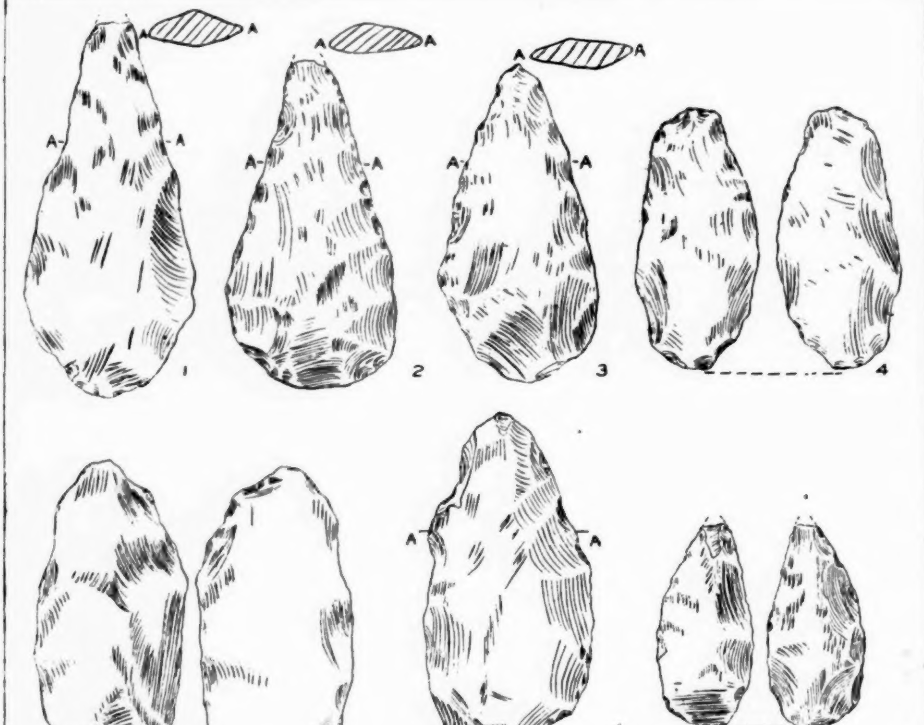

FIG. 2.

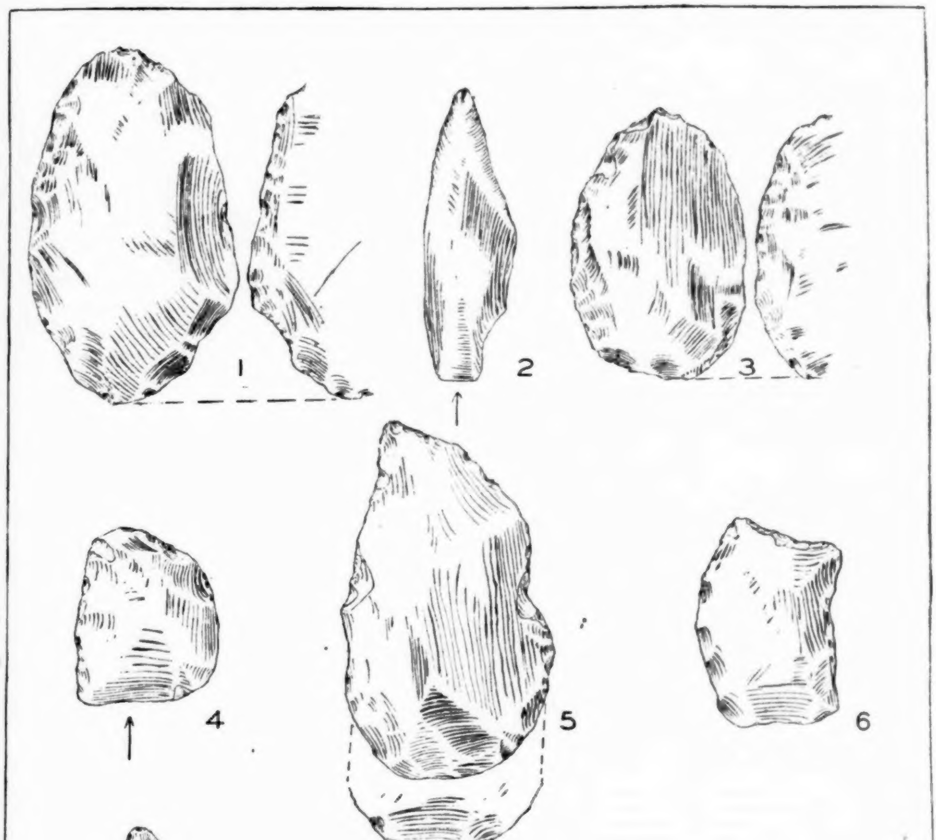

FIG. 3.

than is the case with the cleavers. The upper surface indicates that some of the flakes were struck from prepared cores, fig. 3, Nos. 1 and 3.

Other Flake Tools.—The majority of the flakes recovered show little or no evidence of retouch, fig. 3, No. 9; those which do, however, show typical resolved flaking forming the working edge. Two scrapers are illustrated, fig. 3, Nos. 4 and 6: the bulbs have usually been removed by secondary trimming, the arrow denotes position of bulb.

One specialised form of flake tool or point must be mentioned separately; this is plano-convex in section and shows careful trimming from the main flake surface all the way round the perimeter, both ends converging so that in shape the tool is biconvex. Although only one such implement was found yet this form appears to represent one of the specialised end products of this industry, fig. 3, No. 7.

Discs.—These are small, not more than 3–4 inches in diameter, are biconvex in section and show flaking on both sides all the way round the circumference. They are possibly small, unstruck, prepared cores, fig. 3, No. 8.

Stone Balls.—A number of round lumps of basalt were noted which, although greatly weathered, may represent the "bolas" stones which are elsewhere associated with this culture.

Technique.—Both the Clacton and Levallois techniques were employed by the makers of this industry, the former being the one most usually met with. A number of large, unprepared cores were seen, flakes having been removed from one or more platforms. Prepared cores are much more rare, the only good example noted is approximately circular, 8 inches in diameter, with a deep back, the upper surface showing where four large flakes have been removed, the under surface for half the circumference showing crude trimming. Flakes vary in size from just over 7 inches to 2½ inches along the long axis. Striking platforms show angles of from 103° to 145°; bulbs are always flat, and on a number of flakes have been removed subsequent to the removal of the flake from the core; this appears to have been done by detaching flakes from the upper surface on what was originally the platform, thus either removing the bulb entirely or else reducing the thickness of the butt. Flaking was usually parallel and from the direction of the platform on the smaller examples; some of the larger specimens show crude radial flaking. A very few blade-like flakes were noted, but usually with a marked ridge down the centre. These are probably redirecting flakes, but the one example figured, fig. 3, No. 2, with intersecting flake surfaces may indicate knowledge of the burin technique. This example is too weathered, however, to determine the direction from which the "burin" flakes have been removed.

Such, then, is the Gondar industry, and it remains merely to indicate

its affinities and show our reasons for assigning it to the Fauresmith culture complex. That our own industry is evidence of the contact of the *coup de poing* and flake technique is clearly demonstrated from the above description, the emphasis being on the core tools, which outnumber the associated flake implements. From an examination of the well-finished and finely made end-products from this home and factory site it will be seen that we are in fact dealing with an industry denoting that phase of contact between the final stage of the African Handaxe Culture and a flake-using people. In this case the hybrid industry resulting shows a predominance of the *coup de poing* element with assimilated traits of the flake technique. When we compare the East African Fauresmith (or Nanyukian), the South African Fauresmith and that from Gondar, we see very little difference in types or technique. As is to be expected, the Gondar industry approximates more to the East African culture perhaps than to the South African, the two former being a slightly cruder counterpart of the latter, which, being later in date, shows greater development and slightly more refined end-products (4). Gondar is the farthest north, I think, from which this Fauresmith culture has yet been recorded.

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SHORT NOTES ON STONE AGE SITES AT YAVELLO, SOUTHERN ABYSSINIA.

By J. Desmond Clark, M.A.(Cantab.).

(With two Text-figures.)

(Read August 11, 1943.)

While serving in Abyssinia with the East African Forces I was able to carry out several rather rapid examinations of archaeological sites in a number of different localities in northern, southern, and eastern Abyssinia. The following notes concern the examination in February 1942 of several small rock shelters in and around the village of Yavello in southern Abyssinia.

Yavello lies in the Galla-Sidama province, about 500 miles south of Addis Ababa, 45 miles north of Mega, and 70 miles from the Abyssinia-Kenya frontier. The country here is undulating and hilly with many granite outcrops in which the shelters are situated. Yavello itself lies at the head of a small valley at a height of 1820 metres, and is surrounded on three sides by granite hills, but it is only on the higher slopes that any large trees (*Podocarpus*) are found, the remainder of the country being covered with thornbush, the Acacia predominating. Water is adequate but not abundant.

On the left-hand side of the Algé-Addis Ababa road, where it leaves the Yavello valley and three miles from the village itself, a number of small rock shelters are situated in a massive granite outcrop. Several of these had been cleared by the Italians, who had used them for gun positions commanding the road from Mega to Yavello. The most interesting of these shelters was at ground level, where, under an overhanging wall of rock, deposits to a depth of some 8 feet had accumulated. The whole of the centre part of the deposits abutting on to the back wall had been dug out to form a gun-pit, and thrown round the perimeter as a semicircular parapet. The sequence of deposits shown here was as follows: One foot or so of fine grey sandy dust with a little humic matter and containing a microlithic factory debris and semi-mineralised fragments of bone. Five feet of red to buff earth, concretionary in places with a large number of granite boulders interspersed at different levels throughout; these had presumably fallen from the rock above. This deposit contained heavily mineralised fragments of bone and teeth, while flakes, cores, and a few

implements with undoubted Middle Stone Age affinities also occurred. From an examination of material collected *in situ* and from the dumps surrounding the shelter it seems probable that this assemblage should be assigned to the East African Stillbay culture complex. Implements from this deposit are illustrated in fig. 1, Nos. 23–31.

At 5 feet from the surface the granite boulders become larger and more numerous and almost form a layer across the deposit. Beneath this in places is found a red earth similar to that immediately above with occasional pieces of artificially fractured quartz embedded in it. At 6 to 8 feet the granite floor rises steeply from left to right, sloping quickly down towards the back of the shelter.

About 300 yards from the shelter described above is a second, also at ground level. This one is formed mainly by two massive rocks leaning against each other. The floor space is triangular with the apex at the back of the cave. The maximum depth is about 25 feet and the maximum width, at the entrance, 15 feet. Much of the right centre of the shelter is taken up by a large boulder. In elevation the shelter is also roughly triangular, the apex being the roof which is open through a narrow chimney to the air above: the angle of slope of the walls is about 60°. A small excavation 2 × 4 feet was made here. The upper 4 inches yielded only a few sherds of a rather coarse pottery. Beneath this and to a depth of one foot was a deposit of fine black earth or dust containing the debris and a few implements of a microlithic industry. This deposit also yielded some well-weathered sherds of a thin, well-made pottery. At a depth of 1½ feet the uneven granite floor of the shelter was encountered.

The following is a brief description of the Stillbay material from Cave 1 and of the microlithic industry from Cave 2.

Shelter 1: East African Stillbay Material.

For the most part the material here is in a fresh condition showing little weathering or abrasion other than from use. The greater number of implements have a calcareous incrustation which is very difficult to remove. Material used is predominantly semi-crystalline or crystalline quartz, but chert, silcrete?, and quartzite also used; no obsidian noted.

(A) *Cores.*—For the most part small prepared cores of the "tortoise" variety, 1 inch to 2 inches in greatest diameter, spheroid with subconical section and deep back (fig. 1, No. 26). One only of the discoidal variety was found. I believe that small cores of this type, besides any secondary use to which they might have been put, are the end product after a large core has been utilised and reworked a number of times. Trimming is radial and typical of this culture complex. One typical unprepared core was also found.

(B) *Flakes.*—Those with both prepared (fig. 1, No. 30) and unprepared platforms occur, the former predominating. Flakes are for the most part

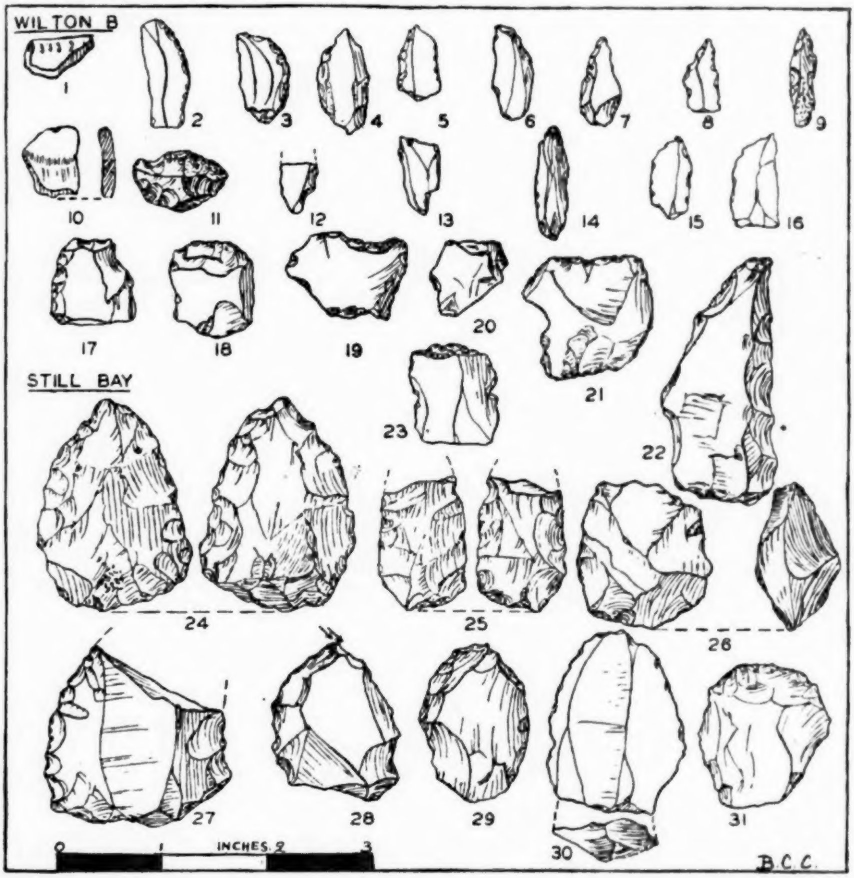

FIG. 1.

thin with parallel and radial flaking on the upper surface. Platforms are usually straight, bulbs usually not pronounced.

(C) *Scrapers.*—A small miscellaneous collection. One small butt scraper (fig. 1, No. 23), and scrapers on flakes (fig. 1, No. 31), and scrapers formed by secondary trimming down one or more of the long sides of a flake (fig. 1, Nos. 27 and 29).

(D) *Burins.*—Two examples—convex and straight angle burins were recovered (fig. 1, No. 28).

(E) *Bifaced Points.*—Two leaf-shaped examples only; one rather crudely made in quartz with fairly thick section showing some resolved flaking (fig. 1, No. 24); the second (fig 1, No. 25), which has lost its point, is more delicately made with thin section and typical pressure flaking. No unifaced points were recovered.

(F) *Faunal Remains.*—Comprise a fragment of pig molar, one complete antelope molar, the fragment of another embedded in a calcareous matrix, and numerous artificially fractured pieces of bone. All are mineralised.

Such is the Stillbay industry, and, although it is of a somewhat sparse nature, there is yet enough for us to note the similarity with the Somaliland Stillbay, which, it is hoped, will form the subject of a separate monograph after the war.

Shelter 2.

The material can be roughly divided into two parts—that found from the surface down to a depth of 6 inches, and that taken between that level and bed rock.

(i) *Surface to 6 Inches.*—The chief constituent of the upper layer, besides microlithic debris, was numerous sherds of pottery, the edges usually not greatly abraded. They comprise sherds from 2 to ½ inch in greatest diameter and ¼ to ⅓ inch in average thickness; of a usually fine, well-fired, dark-brown or black clay with felspars. The sherds, which appear to be derived from shallow bowls and gently-shouldered, round-based pots, are undecorated except for one sherd which shows a band of three rows of oblique stylus impressions roughly pressed into the clay before firing: length of these impressions varies between ¼ to ½ inch. The one rim sherd recovered shows a thickened and flattened rim gently everted—many of the sherds show evidence of burnishing on the outer surface.

Two sherds come from a different type of pot. This is made of a red, well-fired clay containing sometimes quite angular fragments of quartz. Average thickness 4 mm.: one a rim sherd, and one of the largest found, shows that both probably belonged to an undecorated shouldered pot, burnished only on its outer surface. It recalls the water pots made by the local Boran. The rim is flattened but not thickened.

One other object of interest came from this horizon: this is a curved fragment of fine-grained sandstone, 1 inch between the ends, and ¼ inch wide with rectangular section. The fragment presumably once formed part of a stone ring or armband—the inner diameter having been approximately 2½ inches. The inner and outer edges of the ring have been ground

and polished, while the top and bottom sides are rough, but it seems as if these had at one time been similarly polished and rounded and have split and fractured due to weathering.

This layer also yielded one well-worn human molar.

(ii) ***From* 6 *Inches to* 1½ *Feet*.**—Contained the greater part of the microlithic factory debris and implements—those found above being probably due to artificial displacement. The material used was mainly chert, quartz, and a very little obsidian. The industry consists of the following types:—

(a) *Cores*.—These are typical and need no description—cores with one, two, and sometimes three working platforms occur.

(b) *Flakes*.—All, with three exceptions, are typical microlithic, thin-sectioned flakes, and where the platform is present it is always simple and unprepared. Parallel flaking is the rule, bulb is flat.

(c) *Lames Écaillées*.—Fourteen of these were recovered, of which 10 were made from quartz. The term is perhaps a misnomer when applied to these implements as some, as in Rhodesia, are made from—besides flakes—convenient lumps of quartz. All, however, show the typical *écrasé* scars either at one or both ends. There is no doubt that they were the implements for the fabrication of the backs of the microliths (fig. 1, Nos. 20 and 21).

(d) *Scrapers*.—These are mainly rather badly made thumb-nail scrapers (fig. 1, Nos. 17 and 18). Fig. 1, No. 11, was found half-way down the side of a donga about ¼ of a mile from the shelter. It is made from obsidian and is the finest example found, but may of course not belong to this industry. Two hollow scrapers, one of which is figured, fig. 1, No. 19, were found also. The only non-microlithic implement is presumably some kind of scraper or fabricating tool (fig. 1, No. 22).

(e) *Microliths*.—Twenty-six, some broken, were found. Compared with the typical Kenya or Rhodesian Wilton they are poorly made and undoubtedly show a degeneration in technique. The backing is usually carelessly and roughly executed, and in some there is little or no attempt at symmetry. Three types were found: (i) the largest number are microlithic backed blades of Chatelperron form, the true crescent is absent. On the majority the bulb has been removed by secondary trimming, but on some it is still present. Backing is usually done from the flake surface. Two forms are represented, those with flat section and shallow backing and those with subtriangular section and steep backing (fig. 1, Nos. 2 to 8) are examples. (ii) The second type consists of a pointed microlithic flake sometimes, though not often, showing a little secondary work, with signs of use on both edges; these were presumably points of some kind (fig. 1, Nos. 14 to 16); one example of a badly made but nevertheless typical

double-backed point was found (fig. 1, No. 9); the former types are possibly a degenerate form of the latter. (iii) The last type, only one unbroken example of which was found, are flakes showing a notch removed at the base, perhaps to facilitate hafting. The one unbroken example may have been used as some form of chisel or transverse arrowhead (fig. 1, Nos. 12 and 13).

(f) *Pottery.*—Some very small sherds of a thin, well-made pottery were found associated together with a few similar to those described above. Average thickness is from 3 to 5 mm. The paste is fine and contains felspars and some fine quartz. In colour it varies from dark red to dark brown; some of dark brown paste are red on the surface. The outside surface was always burnished and sometimes the inside as well. It is not possible to determine the pot forms as the sherds are too small and all edges are well smoothed. One rim sherd was found, however, showing a simple rounded rim with a series of small finger-nail (?) impressions round the outside edge (fig. 1, Nos. 1 and 10).

(g) Two small pieces of entirely oxidised copper. These formed one piece when found, but it was unfortunately broken in removal. That they appear to be derived from some beaten copper object is all that can be said. An assay by G. Bond showed a very high percentage of copper, but with some very small quantities of another mineral, perhaps tin.

(h) Several polished and striated pebbles and lumps of haematite and manganese ore.

The microlithic crescents, scrapers, and points together with the pottery suggest that we are dealing with an allied if somewhat degenerate form of the Wilton B culture of Kenya. Its association here with an apparently worked fragment of copper is of interest.

Both sides of the shelter to a distance of 10 feet from the entrance had at one time been covered with a number of paintings in a red pigment. Owing, however, to weathering, flaking of walls, and rain from the roof these have nearly all been destroyed or else rendered unrecognisable. Two or three, however, remain sufficiently distinguishable for tracing. The best preserved of these is seen in fig. 2, No. 1, and was found on the right-hand wall about 5 feet from the floor of the shelter and 6 feet from the entrance. It appears to have escaped the weathering to which all the remainder have been subjected and indeed a slight overhang has protected it from rainwash. The figure, which is in a rust or brick-red paint, is a schematic drawing though it is not possible to be certain what it—or for that matter any of the figures—is meant to represent. Possibly this one might be a schematic representation of a cow. Fig. 2, No. 2, was found on the same wall. It was 1½ feet to the left and slightly below that just described. This figure was in the same paint, but was greatly weathered

Fig. 2.

and parts had completely disappeared. It is possibly a variation on the same theme as the previous figure. All other paintings on this wall were weathered beyond recognition and were impossible to trace. Fig. 2, No. 4, was found on the left wall about 5 feet from the floor and the same distance from the entrance. It is in the same brick-red paint but is much faded. This painting shows a group of three tectiforms, a motif well known in certain art groups. On the roof at the left, about 8 feet above the floor, are several more paintings, one of which, fig. 2, No. 3, was sufficiently clear for tracing. Again it is impossible to state for certain what this figure is meant to represent, but the thin antennæ-like lines and tail show that the paint was applied with some care. This painting and two or three others adjacent were in a slightly darker (cherry) red. This is perhaps due to the better preservation under the roof of this group. Although no superposition of the two red paints was observed and the styles and techniques were the same, the colour difference makes it at least possible that they belong to two separate periods of painting.

All these red paintings are of a highly schematic character recalling the Copper Age art of Southern Spain, the schematic group of paintings in Northern Rhodesia, in the Katanga Province of the Belgian Congo, and in North Tanganyika. I consider it very likely that some connection will be found to exist between the Tanganyika group and these at Yavello. The discovery of ground and polished haematite with a degenerate industry similar to the Wilton B culture of Kenya in the floor of the shelter suggests that this red group of paintings may have been the work of the makers of this microlithic industry.

In addition to the red schematic paintings described above was a second and later series in a dirty white paint. These are not greatly weathered, except where the water trickling down the walls from the chimney in the roof has obscured them. Nearly all these dirty white paintings are on the left wall or roof and are not so numerous as those of the previous series. Nearly all these figures appear to represent the zebu or humped cattle. Fig. 2, No. 5, is a typical example; others are more schematic. Direct superposition of the white series on the red (fig. 2, No. 4) shows that the former are the later in date. The paint is of a thick coarse nature and has been daubed on carelessly, probably with the finger. The "fatty" consistency of the paint can also be clearly seen showing that the paintings cannot be of any great age. As zebu cattle are known to have existed in East Africa at an early date, their representation here does not unfortunately assist in dating the paintings, which are probably of no great antiquity, and the "occulate" motif is reminiscent of similar ones seen on the headstones of the Galla and Boran graves. As far as I know this is the first recorded instance of schematic paintings from Abyssinia; the only other caves

containing paintings that I know of are the Grotte D'Istria and Sirte group, near Dire Dawa, but these are in a naturalistic style. The three other rock shelters visited, although they all showed evidence of occupation by a microlithic using people, yet contained no evidence of paintings.

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CLIMATES AND PRE-PALAEOLITHIC ARTIFACTS OF THE WITWATERSRAND.

By J. C. Smuts, Jun.

(Communicated by C. van Riet Lowe.)

(With Plates I–III and two Text-figures.)

(Read October 13, 1943.)

There is, as Reid Moir and others have pointed out (1), a trend in present-day prehistory to regard certain aspects as more or less established facts. One is to assign a more remote origin to primitive man than was customary a generation ago, especially where he was considered in a geological or chronological setting. Another is to assume that man in the remote past had advanced much farther along the path of material progress than earlier archaeologists were inclined to believe. With these conclusions few people could justly disagree, for the whole theme of present-day research points increasingly in this direction. It may not sound a very revolutionary outlook, but, with its acceptance, our knowledge of the Dawn Stone Age is likely to progress apace.

The study of the pre-palaeolithic has, on the whole, always been somewhat unsatisfactory and has resulted in inconclusive results and much vacillation. This has virtually been inevitable, for not only have past investigators entered this field with a perceptible personal bias, but the whole sphere for study in Europe is limited and unsatisfactory. There are far too many natural complicating factors. Flint is not only a very brittle medium, but also an unstable one. It renders discrimination between natural and artificial fractures extremely difficult, while at the same time facilitating the act of chipping. Its value as a medium for archaeological study is therefore somewhat limited.

In addition, confusion has been augmented by a number of other most important complicating factors, such as only result in the frigid climes of Europe. It is only recently that we have learned to appreciate the full meaning of solifluxion or ice creep, and the considerable effect it appears to have exercised on flint nodules. It is only recently that we have seriously studied superincumbent pressures and soil movements, or taken account of glacial weight, crush, and drift. Hence it is only natural that

now, for the first time, we see the problem in its true perspective. This vast new field of science we owe largely to the painstaking and intrepid work of Breuil. Conclusions based on these latest studies have swept away many of our past ideas. But at least speculation and guess-work have been somewhat eliminated.

No longer need we ruminate vaguely on the Cantal and Harrissonian flints. Of the former Breuil remarks: "The study I personally made of the Oligocene and Miocene flints in Cantal, and the conditions under which they were found, force me to consider them as exclusively natural and due to very considerable and repeated landslides, and to pressure in alluvial beds which had been tilted and are often standing erect." The Harrissonian flints he describes as "exclusively natural and due to phenomena produced by glacial solifluxion having affected Abbevillian and Acheulean tools in these deposits, where they meet at some depth" (2).

If we accept Breuil's views as conclusive, their significance is obvious. They act, firstly, as a timely reminder that we must study the Stone Age not merely from examples in a show case, but rather on the spot, where we are able to make allowances for all extraneous influences and are able to establish both cause and effect. Secondly, they indicate that the Stone Age in Europe does not go back quite as far as many people had hoped, and as far as we are able to ascertain at present, certainly not into the Early Miocene, though Sub-Red Crag takes it back comfortably into the Pliocene. In Africa, certain early Kafuan and Pebble types may be traced to an equally remote, if indeed not more remote, origin. The pendulum of interest is swinging slowly from Europe towards Africa. The abundance of specimens here, and the wide extent of their distribution, far overshadows any Pliocene deposits in Europe. In Africa the problem resolves itself more into a geological than an archaeological one. It is not a question of establishing the artificial origin of artifacts—for on this point there is virtually complete unanimity—but of establishing their geological age and setting.

Here in the temperate climes of this great *terra incognita* the whole question of the earlier chapters of prehistory is still only superficially explored. Yet, though few definite conclusions have so far been formulated, much useful work has already been accomplished over widely separated areas and under a diversity of different conditions. The problem has been tackled from the "cause" and not the "effect" end.

But we have other advantages here as well, in that our evidence is all more positive and straightforward, with few of the complications enumerated for Europe. In Africa we deal with tough, stable quartzites. We do not have to worry about solifluxion, creep, glaciers, or undue tilting. It is very seldom that we need give superincumbent pressures more than a

fleeting thought, for strata are usually thin and shallow. Yet there is still present, to the same degree as in Europe, the rough forces of swollen rivers, the heavy tread of pachyderms, the flying hooves of antelope, the sun, rain, and grass fires. In brief, Africa is a better museum for the study of the opening phases of the Stone Age. There is only one major drawback, that it is difficult to date beds because of a regrettable absence of the commoner fossils. Time alone will solve that deficiency.

The pre-palaeolithic types of the Union have not, in the past, received the attention they merit. This has been due to a variety of causes, some justified, others mere superstitions. The controversy shrouding the older types of Europe has introduced a measure of scepticism into the contemplation of African types. In addition there were the problems presented by a few actual crude artifacts: Were they old? Were they, indeed, artifacts? Secondly, the country is so rich in artifacts of Stellenbosch and later periods that one is apt to be fascinated by them to the exclusion of all else. The beautiful symmetry of the handaxe is a strong hypnotising agent. One forgets to look carefully in the strata still deeper down, or fails to notice the insignificantly chipped pebbles, dirty and decomposed. With the handaxe people were quite at home, for no uncertainty detracted from its interest and it was spread over half the world, from Europe to Africa, from Asia Minor through India to the East Indies. Thirdly, the older types are generally considered to be poor to look upon, uninteresting and of limited importance. Whether this is so, the reader will be able to gauge for himself.

In this paper the writer will endeavour to give some account of the pre-palaeolithic on the Transvaal Highveld with special reference to the new types of artifacts encountered, their stratigraphy and climates obtaining during their deposition. In some respects this paper is a sequel to a former one (3) published in 1938. Yet the whole problem has been treated here in a much broader aspect and a clearer background has been substituted. The passage of the past half a dozen years has not only added much to our previous knowledge, but some ideas have, of necessity, suffered a slight metamorphosis in maturity. But nothing has been radically altered. Since 1938 considerable work has been accomplished by van Riet Lowe, and more latterly by Breuil, on the Vaal River terraces. Broadly speaking this evidence confirms the writer's conclusions based on the old Witwatersrand pan gravels.

It is not here deemed necessary to repeat detailed sections of the various sites, or to reiterate correlations, or to establish the synthesis of climatic deductions. Suffice to remark that correlations are based on the typological content of beds and that climates are deduced from the geological composition and ferruginous and calcareous impregnation of beds. To

Sections of Beds of a Few Typical Transvaal Highveld Sites.					Deduced Climates.	Pluvial Period.	Associated Artifacts.
Rietvlei Dam.	Brentwood Park.	Benoni.	Pomona Pan 1.	Pomona Pan 2.			
Bed PC 1′–6′ Pebble bed highly ferruginous and clay	Bed D 6″–1′ Gritty subsoil	Bed C 1′–4′ Grit bed slightly ferruginous	Bed D 6″–1′ Hard grey sandy subsoil	Bed D 6″–1′ Hard brown slightly ferruginised subsoil	Dry Wet	Fourth Early Pluvial	Advanced and Developed Benoni Pebble and Advanced Alpha
Bedrock	Bed C 1′–3′ Very hard dark-brown ferricrete	Bed B 6″–3′ Hard red ferruginised gritty laterite	Bed C 1′–3′ Red loose sandy ferricrete	Bed C 1′–2′ Hard red ferricrete	Dry Wet	Third Early Pluvial	Later Benoni Pebble and Alpha
	Bed B 1′–2′ Very hard pale silicified clay	Bed A 6″–2′ Very hard red "fused" highly ferruginised grit bed	Bed B 1′–3′ Very hard brown ferruginised gritty bed	Bed B 1′–2′ Hard brown ferruginised grit bed	Dry Wet	Second Early Pluvial	Early Benoni Pebble and Early Alpha
	Bed A 1′–8′ Deep red ferruginised gritty clay	Bedrock	Bed A 1′–4′ Hard brown ferruginised pebble bed	Bed A 1′–3′ Hard brown ferruginised grit bed	Dry Wet	First Early Pluvial	Earliest Benoni Pebble

FIG. 1.—Summary of a few typical sections of Pan beds of the Witwatersrand. All beds are implementiferous.

these facets have been added evidence from former pan levels, patination, abrasion, and other relevant features. In fig. 1 will be found a summary of the strata, artifacts, and deduced climates of the various sites.

Witwatersrand Pans.

This paper has been based largely on the evidence afforded by the old pans of the Benoni area. Virtually all beds there are implementiferous and collections have been made from the various horizons. The Witwatersrand pans are typical of the Karroo type pan so common over most of inland South Africa where the country is flat and exposed. They are probably the result of wind erosion (4), and range in diameter from a hundred yards to a few miles. They are shallow and symmetrical, with flat bottoms and gently sloping sides, infrequently contain water and seldom perennial. There are no streams running in or out and the perimeter is smooth and unbroken. Catchment areas are small, rarely exceeding a dozen times pan size, and most usually only three or four times as large.

They depend for their water exclusively on catchment run-off. The indications are, therefore, that pan levels should bear some rough relationship to precipitation and act as an indication to past climates. There is no question of turbulent waters in these pans and no physical forces capable of swirling and concussing pebbles. Forces of erosion need scarcely be considered. Pan levels indicate rainfall and are quite independent of any other physical forces that complicate studies in river basins. The importance of pan gravels can thus readily be appreciated. But they are of added importance in that they furnish more complete records than river gravels. For these latter are only aggraded when the pluvial cycles have passed their peak, floods have subsided and the more sluggish waters become over-loaded. This period of decline normally only occurs after the mid point of the wet phases, and consequently river gravels only represent the closing half of pluvial periods. Pan gravels, on the other hand, being independent of the forces of erosion, form gradually during entire wet periods and therefore give a more accurate reflection.

The ferricrete and calcareous impregnations of the higher pan gravels are indicative of diminutions of precipitation after pluvial or wet phases. Hence a succession of impregnated high-level gravels indicate a corresponding number of climatic oscillations. This has formed the basis for the climatic deductions of this paper. Correlation of beds from various pans is affected by comparing the various sequence of strata and establishing zones of overlap. The chronological basis depends on the stone artifact as the dating fossil. In the limited areas involved this assumption is permissible.

Pebble Type Artifacts (General).

Though the "pebble" terminology is in fairly regular use and understood by most people, it might nevertheless be advisable to give a brief explanation before proceeding with the paper. The term "pebble culture" embraces a wide range of early core types and covers a protracted time period. Wayland calls his Pebble types "Kafuan" (5). Leakey prefers his "Oldowan" (6). In South Africa the general name "pebble" seems to be favoured and is the one adopted by the writer. In this paper the pebble varieties of the Witwatersrand will be more specifically designated the "Benoni Pebble Culture."

Tools of this type are constructed on actual smooth or subangular pebbles, and, as much of the original cortex is still retained, continue to present the aspect of trimmed pebbles. In construction and conception they are elementary in the extreme. In age they handsomely precede the Abbevillian.

Early Flake Types (General).

The co-occurrence of rude flake types of artifacts together with the pebble varieties is a well-established feature. Leakey and Wayland have noticed it in East Africa, van Riet Lowe (8) and Breuil on the Vaal River, and the writer on the Witwatersrand and in the Cape. The flake type is referred to generally as "Old Flake" or "Early Flake," and as this name is in wide use as well as being descriptive, it will be retained. At present it is impossible to state the relationship between Flake and pebble types, but the fact that they are almost invariably found together does indicate that there is a close affinity, if not complete identity. Van Riet Lowe does not think that they bear separation, and Breuil, too, is very sceptical on this same point. Yet the writer feels that the problem is more complicated than we imagine. For when one considers the specialised form of Flake (Alpha) and its advanced psychological aspects it becomes almost impossible to consider them parts of the same entity. This will be discussed in some detail later in the paper, when the Alpha Flake is considered.

Typologically the old Flake type embraces virtually all artifacts that display bulbs of percussion, and shapes vary from simple flake and blade-like forms to more elaborate and lavishly prepared artifacts. Sizes are small and platform angles wide, with flaking having a longitudinal tendency.

The Kafuan of Uganda.

This rather rude industry was initially located by Wayland in the high terraces of the Kafu in Banyoro, Uganda, and is of extremely great antiquity (5). But since then Wayland has found it to have a very much more generous distribution, and many subdivisions have been incorporated.

It is evident that the Kafuan comprises a wide diversity of types and that it was of extremely long duration. It commences with the crudest types imaginable and terminates finally with ones almost equivalent to Leakey's Oldowan. On the time scale the duration factor is many hundreds of thousands of years, if indeed not millions. Typologically it represents virtually the entire range of man's early efforts at tool-making.

The Early Kafuan specimens are as crude and elementary as is permissible in artifacts. They consist simply of smooth, waterworn pebbles split amidships by a single blow, though sometimes the fracture exhibits more than one chipping blow. Often these pebbles are fairly robust, but large or massive sizes are not favoured. Ruptures occur not only along lines of greatest weakness, but along all others, including those of greatest strength. This certainly does not signify a natural agency. Add to that Wayland's assurance that these pebbles were found in positions where they could not have been deposited by natural forces, and that they must have been transported there artificially by some animal, and the case for tool-making man is virtually conclusive.

A further feature of the Kafuan is the co-occurrence of crude Flake types together with these pebbles, throughout practically the entire series.

From the typological aspect the writer agrees with Breuil that the Kafuan of East Africa is satisfactory and obviously of artificial origin.

But chronologically the position is not so clear, for Wayland maintains that his Early Kafuan is probably of late Pliocene age. The types in the Union which appear to bear a similarity to the older Kafuan ones the writer believes to be possibly of Mid Pliocene origin. It sounds a minor point, but is apt to be very disconcerting when comparisons are attempted. There are two possible explanations: (1) either they were contemporaneous, in which case merely a difference in the interpretation of the Pliocene is involved, or (2) they were not contemporaneous, in which case there could be no connection, and the Kafuan must be considered as a later and arrested culture. The former explanation is favoured, but it would be wise, however, to suspend judgment till more is known about their chronology.

The distribution of the Kafuan is not limited to Uganda, but embraces Kenya and Tanganyika as well, and probably areas in North and North-West Africa, and possibly Southern Europe. Its presence in the Union is fairly firmly established.

The assemblage collected by Wayland at Belfast (Transvaal) and housed in the Bureau of Archaeology, Johannesburg, is not satisfactory. It appears to contain a confused admixture of various ages, collected off an old land surface, the most recent elements being of Middle Stone Age facies. Some of the specimens are very similar to the Kafuan and Oldowan, and are probably of similar age, but a large proportion are more recent.

Comparison between the Kafuan and European flint types is not possible, for Europe has nothing remotely resembling it. The Transvaal has counterparts in the pan gravels of First Early Pluvial age and in the 150-foot Vaal River terrace at Windsorton.

The Oldowan of Tanganyika.

This group was initially located by Leakey in the Oldoway (Olduvai) Gorge in the Great Rift Valley of East Africa (6). The Oldowan Culture belongs to Bed 1, or the lowest implementiferous horizon, of this site. Climatically it predates the Abbevillian by a complete pluvial cycle. Typologically it is long pre-Abbevillian. Oldowan artifacts constitute part of the more recent portion of the Benoni Pebble Culture series, and in aspect consist of smooth, roundish, waterworn, and subangular pebbles, rudely trimmed into cutting or chopping edges along part of their periphery. The principle involves the preparation of a platform on the dorsal surface and steep chipping from it on the ventral face. Much of the cortex is retained and forms a convenient grip for the hand. Artifacts are thick and clumsy and usually of medium to large size.

In age the Oldowan is equivalent to a very advanced form of Kafuan, though it is uncertain if the family connection exists. Leakey, too, is doubtful on this point (6). It appears to have the same geographical distribution as the Kafuan, and is likewise characterised by an admixture of Flake types. In virtually all respects specimens from Bed 1 at Oldoway are identical with the Fourth Early Pluvial specimens of the Witwatersrand and with some of the examples from *circa* the 40–60-foot levels in the Vaal terraces.

No comparison with European flint types is possible, though there is probably a connection with the quartzite ones of Southern Europe.

European Pebble Types.

In 1941–42 Breuil found in Portugal, in a raised beach at the 90-metre level (Sicilian) at three places to the north of Sierra Cintra, a very abundant pebble and Flake industry. At Casablanca in 1941 he found similar types in a 90-metre marine beach directly underlying workshops of Clacto-Abbevillian age (2). He suspects that the high raised beaches of the south and east littorals of the Union might yield pebble types as well.

The North African and Portuguese artifacts are not of flint, and are therefore of added interest to us. Breuil says many of them are quite indistinguishable from specimens collected on the Vaal or Witwatersrand. It is obvious that affinities of these widely spread groups are much closer

than initially believed. We look forward eagerly to a publication by Breuil on the subject.

Choukoutien Culture.

Breuil is at pains to point out that this is not a pebble type. It is true that numerous pebbles and fragments of discarded rock were used as hammer stones or anvils, but they were used merely in the construction of the actual implements. These latter are of quartz and constructed from angular blocks quarried in the neighbouring mountains. The quartz is chipped by a bi-polar or specialised anvil technique, and rather cleverly trimmed (2). The resultant artifacts are generally small, and both culturally and typologically they are remote from any other Western World or African industry. It is not permissible to compare the Choukoutien to the Icenian, as Leakey does (7).

Early Pluviation on the Witwatersrand.

Since the beginning of geological time the climate of the world has been subject to certain periodic or rhythmic fluctuations between moist and dry. We shall only concern ourselves with certain Tertiary and Quaternary ones. It is not within the scope of this paper to discuss the causation of these phenomena, for they are of extreme complexity. Suffice to remark that the evidence to hand persuades us to the belief that such oscillations did exist and that the life of primitive man was bound up intimately with them. The periods that concern this paper are the early Pleistocene and a big portion of the Pliocene preceding it. The two are generally presumed to have been separated by the long arid Kalahari period in South Africa, and this seems feasible. The duration of the Pleistocene was about a million years and in Europe it was marked by the four ice advances of the last Great Ice Age. The duration of the Pliocene is probably of the order of ten million years, and climate during this period was generally warmer than in the succeeding one. Both periods are marked by considerable climatic as well as crustal instability.

How many Pliocene wet or pluvial periods there were in South Africa cannot be stated, but only the last four are of interest to us, as they appear to be the only ones to contain evidence of early man. Beyond the limit of the first of these four there is no sign of recognisable artifacts, and we may assume that man was still in an anthropoid stage.

The Pleistocene is marked by two double-peaked pluvials and two post-pluvials, but these will not concern us, for they have already been described in detail by many writers. To distinguish between the pluvial periods of the Pliocene and Pleistocene the writer has called the former

ones "Early Pluvials," while the latter remain simply "Pluvials." They are classified in this paper as follows:—

First Early Pluvial (the oldest).
Second Early Pluvial.
Third Early Pluvial.
Fourth Early Pluvial.

First Pluvial (Part 1).
First Pluvial (Part 2).
Second Pluvial (Part 1).
Second Pluvial (Part 2).

First Post-Pluvial.
Second Post-Pluvial (the most recent).

All are separated by relatively dry inter-pluvial phases.

The term "pluvial" is used to indicate any climatic period during which precipitation was comfortably in excess of present-day figures, irrespective of whether it was continuous or intermittent. Similarly "dry" is used to indicate relative dry and intermittently dry climates. As these figures are relative, they will vary over different parts of Africa with the changing rainfall. On the Witwatersrand the present annual figure is 30 inches.

Typical Early Pluvial Pan Beds.

Some idea of the nature and composition of these beds has already been given in fig. 1. They are all gritty ferruginous beds of varying degrees of hardness and reddening, and are implementiferous almost without exception. Broadly speaking the earlier beds are consolidated to a greater degree than the more recent ones. The staining and ferricrite adhesion effect grows more marked with age and is often of use in classifying artifacts picked up at random from the debris of excavations. Pan beds in the Benoni area are, on the whole, remarkably devoid of concentrations of pebbles or stones. Usually they consist simply of hard red to brown ferruginous grits, sands and clays. Pomona Pan No. 1 is the one exception, for its lower beds virtually assume the aspect of normal pebble crammed gravels, stones averaging twenty per cubic foot in the bed of First Early Pluvial age. The more recent strata here are almost entirely clear of pebble agglomerations. At Benoni the Fourth Early Pluvial bed averages about eight stone fragments per cubic foot, and of these about 10 per cent. have been utilised by primitive man. The bed preceding it is almost completely devoid of pebbles, containing less than one per cubic foot, of which about 20 per cent. show signs of having been chipped. In the bed of Second Early Pluvial age large fragments of stone are extremely rare and mostly

display evidence of chipping. At Brentwood Park beds are virtually completely devoid of pebbles. In beds of the First and Second Early Pluvials solid objects average one per four hundred cubic feet and almost invariably display evidence of chipping. At Pomona Pan No. 2 stones average about one per ten cubic feet and, as at Pan No. 1, few have been touched.

The general impression is, therefore, that the pebble content of pan beds is small. This renders the possibility of chipping by natural banging, crushing, or pounding together of pebbles extremely remote. In river gravels the issue is usually not so clear.

The ferruginous stain imparted by beds to the "skin" or patina of artifacts varies considerably, but tends to deepen and intensify with age. It is an indelible impregnation, and no amount of washing will remove it. Artifacts of Fourth Early Pluvial age are only very poorly stained, but in those of the Third the stain is deep, and in those of the Second and First staining is considerable. The colour varies from a dull brown to a rich rufous red.

At the Benoni site there is no Fourth Early Pluvial stain on artifacts. Third Early Pluvial specimens are stained red-brown and usually there are patches of hard red clay adhering. It is a persistent, non-gritty adhesion, which is quite resistent to scrubbing. Specimens from the Second Early Pluvial are equally deeply stained, but the adhesions or encrustations are more lavish, very much harder and more gritty. There are bigger additions of brown in the colour, and due to the decomposed and leached state of artifacts, colouring matter has been permitted a deeper penetration.

Of the collections assembled at the various sites, only a small proportion were recovered from actual positions *in situ*. These were picked out from the walls and floors of excavations. The vast majority were collected from piles of excavated rubble and classified by deduction, taking the above-mentioned points into account. Where there were ferricrite adhesions on artifacts the problem was particularly simple, for it solved itself upon simple comparison. In all cases, however, few difficulties were presented and classifications were made with complete confidence.

Witwatersrand Benoni Pebble Types (Detail).

Some indication has already been given of the characteristics of these types. It has been stressed that a vast time period has been covered by this culture and that considerable evolutionary processes had ample opportunity to function. For this reason subdivisions have had to be introduced. The terminology adopted in the previous paper was of the simple "Primitive Pebble," "Lower Pebble," "Advanced Pebble" variety.

But as the existence of artifacts began to be established in the older Early Pluvial beds, this system became rather obsolete and confusing. For this reason it has now been deemed best to use the following revised nomenclature, which takes the various pluvial phases into account:—

First Early Pluvial yields Earliest Benoni Pebble types;
Second Early Pluvial yields Early Benoni Pebble types;
Third Early Pluvial yields Later Benoni Pebble types; and
Fourth Early Pluvial yields Developed and Advanced Benoni Pebble types.

The Earliest and the Advanced types now mark the two extremes of the pebble industry.

The Earliest Benoni Pebble Type.

Artifacts of this group are elementary in the extreme. It is doubtful if we will be able to recognise human workmanship of a cruder origin. This group must therefore be taken, at the moment, to represent the bedrock of prehistoric study.

Its most striking characteristic is its simplicity of technique. Artifacts usually consist, as in the case of the Kafuan, of pebbles showing a simple fracture at some point, this fracture having been produced by striking one or two blows. The commonest form is a pebble ruptured amidships, this parting not necessarily taking place across planes of greatest weakness. This break may subsequently suffer a few rough trimming flakes, but this is not usual. The pebbles employed are usually small, smooth, and somewhat flattish, but there are exceptions.

A variation of this split type of tool is one where merely a chip has been knocked off the one edge, the idea being to provide a jagged cutting edge.

A third type of tool is the notched scraper, consisting of either a single or double notch, and constructed on flat pebbles.

The final type of tool is one which has no definite shape or form, but which merely shows signs of having had artificial attentions. The underlying motive appears to be the desire for a sharp edge.

Only two artifacts of this age are available from the Brentwood Park site, both retrieved from *in situ* positions. They are of quartzite and very badly decomposed. One is of very large size and weighs about fourteen pounds. In shape it is not unlike a large loaf of bread cut across its centre, this cut having taken place naturally along a cleavage weakness. From the edge of this cleavage plane five small secondary flakes were detached, all in the same direction. Whether this trimming was deliberate, or whether it resulted from use of the tool as a chopper, it is impossible to state, though the direction of the flaking suggests the former. The tool was found deep down in Bed A, far from any other hard object, and the

chipped edge was not uppermost. The other tool is an indefinite shape, about 3 inches cubed, with two long flakes detached from one sharp edge. It is difficult to interpret the use of such an artifact unless it was the flakes, and not the core, they were after.

From the Pomona site about a dozen specimens are available, all small in size, and some of chert and quartz, as well as of quartzite. The majority take the form of simple split pebbles. Some display more than one flake scar. Though small in size, they are thick in cross-section and very robust. The object was the production of a sharp cutting edge. The notched scrapers are of more slender proportions and constructed on flat slabs of rock, notches being of about one-third inch radius.

Tools of this group are so crude and elementary that it takes a trained eye to locate them. So far only core types have been recognised, but the collection is so small that it cannot be said with any degree of certainty that flake types did not exist as well. There are specimens that display positive flake bulbs, but whether the intention was to produce flakes or merely to shape cores is not quite clear. In working on these crude types it is well to remember Breuil's truism that "where there are cores, there must be flakes as well."

The Kafuan is the only series comparable with the Earliest Benoni Pebble and the relationship has already been discussed. Certain very high-level Vaal River types appear more or less identical.

The gravels of Pomona are rich in examples of natural fractures, some due to thermal causes, others along lines of weakness, others merely along decomposed sections of pebbles. But it is interesting to note how easily distinguishable these specimens are from the artificially flaked ones.

The Early Benoni Pebble Type.

Artifacts of this group are spread across the Second Early Pluvial, and though still crude in the extreme, present a distinct evolutionary improvement on the previous ones. Here for the first time definite patterns begin to crystallise out and designs are adopted that are to constitute prototypes to tools of the succeeding two wet cycles. Here, too, the flake type of tool makes its initial appearance, and henceforth it is found side by side with the core types throughout the Stone Age.

The old split pebble variety of artifact, in its simplest form, has vanished and its place is taken by something more elaborately chipped and more carefully thought out. One of the basic principles of lithic cultures is here employed for the first time—the preparation of a platform from which to conduct the flaking. It follows, therefore, that this represents the earliest appearance of a true Stone Age industry. Artifacts are much larger than

the former ones, being about 3 inches cubed and weighing about 2 pounds. Subangular pebbles seem to have been preferred to smooth round ones, thus facilitating the primary flaking. Unfortunately few tools are available from this period, so complete descriptions cannot yet be furnished, though it is apparent that the object was the preparation of a jagged cutting or chopping edge.

Brentwood Park has yielded two Early Benoni Pebble types. One is a round smooth pebble, the size of a tennis ball, with a flattish base. From this base two steep flakes were struck alongside each other on the periphery, resulting in a sharp edge. It may serve either as a knife, chopper, or scraper. The other is a massive 10-pound slab of quartzite, triangular in shape and rudely trimmed at the apex with about three blows, these being struck steeply from the flat base. It would serve admirably as a chopper. Pomona has disclosed only a few nondescript examples, one or two being mere split pebbles and possibly factory-site discards. But in others there has been an attempt at something more ambitious, though continuity seems lacking. At Benoni the few examples are badly decomposed and deeply encrusted. They are rough subangular fragments of about 3-inch side, rudely trimmed round part of their periphery, flaking being steep and executed from a natural or prepared base or ventral surface.

Chronologically the Early Benoni Pebble is long pre-Oldowan, but whether the Kafuan has a comparable evolutionary stage the writer cannot state. The very high Vaal gravels display similar types.

The Later Benoni Pebble Type.

The apparently unbroken chain of evolutionary development which marks the earlier phases of the pebble still perseveres. Old ideas are expanded and elaborated, but little new transpires. Tools of this group are the product of the Third Early Pluvial period. Beds of this age are more generously represented than previous ones and artifacts become much more common. The search for specimens becomes less laborious and they may be collected in fair numbers. Consequently the study of the Later Benoni Pebble has been comparatively easy and complete.

Tools are still extremely crude and clumsy, but the fact that small ones are met more frequently does show that flaking was becoming better controlled and meticulous. The range covered included side scrapers, choppers, cutting edges, and special hide-ripping or incising tools. Occasional rough but unmistakable round bolas shapes are encountered, but these probably served as hammer stones and not offensive weapons. The side scrapers are simple developments of the proto-types already described. Stones used are preferably subangular and flaking is done steeply from a

flat basal plane around portion of the pebble edge, the flaking seldom extending round more than half of the periphery. Basal planes are natural, where possible, otherwise prepared. Choppers are not so common and differ slightly from these scrapers in that flaking tends to be done on both sides of the same edge and is hence in two directions. Edges are rough and irregular, marked on each side by two scars, the butt remaining smooth cortex. Cutting tools take no definite shape, the sole purpose being to produce a keen edge on some prominent portion of any fragment of rock. The hide incising or ripping tools are new innovations and obviously specialist tools. Flaking is scant and directed so as to produce a prow-like inclined edge, the sharp tip of the prow being formed by the convergence of flaking on the flat basal plane, from which the steep flaking was directed. In side elevation the shape is rostrocarinate. It is the sharp prow tip that constitutes the cutting edge. Stones selected are smooth oblong pebbles and flaking takes place at one end, three blows sufficing to complete the job. Sizes, 3 to 6 inches.

Chronologically this group is one pluvial phase pre-Oldowan. In facies it is proto-Oldowan. Tools are obviously of artificial origin and definite patterns are easily distinguishable.

The Developed Benoni Pebble Type.

We have seen so far that the Earliest consists of simple fractured pebbles. In the Early type two or three flakes were struck, and in the Later type flaking was more elaborate, but still did not occupy more than half the pebble periphery. And now, in the Developed type we find that flaking occurs around more than half of the circumference. The Developed type is found in the first half of the Fourth Early Pluvial. It marks the final phase of the old pebble series. In types more recent than this the round or spherical shape has disappeared and pointed or slender types make an appearance. But in the Developed type the theme is merely an elaborated Later type, flaking being more profuse and better executed, with occasional intelligent applications of crude secondary trimming. Range of forms is, as before, side scrapers, sharp edges, choppers, hide rippers, and bolases.

This is by far the commonest true pebble type and is the one most frequently recognised by collectors, not only because it is the most conspicuous, but also because it has the widest distribution. Breuil speaks of this type from Portugal and Casablanca. Leakey finds it at Oldoway in Bed 1. Van Riet Lowe noted it in the top of the 60-foot Vaal "Potato" gravels. On the Witwatersrand it is present in greatest profusion, and in the old Cape clays it is by no means uncommon, while in the pebble bed of the Hennops River at Rietvlei it is common.

The study of the Fourth Early Pluvial on the Witwatersrand pans is not satisfactory because beds of this period formed an old land surface for quite a considerable time, and admixtures of tools of various ages occur jumbled together. But at Rietvlei the position is more satisfactory and classifications of this period are based on evidence from here.

The Advanced Benoni Pebble Type.

This series is found in the second half of the Fourth Early Pluvial. Here the theme changes from pebble to proto-Abbevillian and shapes become less round and more elongated and pointed. Flaking is multidirectional and true bifaces make their appearance, as well as rude handaxe shapes. But large areas of cortex still remain. The transformation from the Developed to the Advanced type is sudden. Prehistory had reached a stage where acceleration increased apace, and from here the curve climbs ever more steeply. Man was exercising superior discrimination in selecting materials to work upon, thereby reducing ineffective chipping to a minimum. Hence, where it was required to produce a rude handaxe, an oval or cylindrical subangular fragment was used. Work was concentrated upon the point, butt ends remaining smooth and untouched. Range of tools is still limited, comprising handaxes, choppers, side scrapers, knives, etc.

Up to this stage the chain of evolution from the Earliest Benoni until the end of the Fourth Early Pluvial was unbroken, and it is yet to remain unbroken for some further period. For, in the next wet phase, Part 1 of the First Pluvial, types are encountered that are merely more polished forms of these simple Advanced Benoni specimens. These are the earliest Abbevillian types (after Breuil), the new name for Commont's old Prechellean.

Witwatersrand Early Flake Types.

The Flake type of tool only occurs conspicuously during the Second Early Pluvial, but though no examples have so far been collected from the previous wet phase,' the possibility must not be discounted. In appearance it is simple in the extreme, but its conception and execution show remarkably advanced characteristics. A noteworthy feature of the Flake type is its relatively slight evolutionary development during its protracted existence in three wet oscillations. It appears to have reached considerable development quickly and to have remained at that pitch for a very long time.

Tools are predominantly small, triangular or rectangular in shape, thick in cross-section, devoid of elaborate secondary trimming, and platforms, though faceted, never show more than one or two scars. Artifacts are divisible into two big groups depending upon the technique of their

construction: (1) those that consist of flake splinters struck off the sides of more or less unprepared cores, such as angular lumps of rock; (2) those that had lavish preparation on cores prior to detachment. Both are Alpha Flakes, but the latter has been designated the "specialised" Alpha to indicate its mode of construction. In both cases flakes tend to be long and slender with flaking predominantly longitudinal, and platform angles at 120 degrees. Secondary trimming is extremely rare and bulb undersides are never touched, the bulb being at the butt end of tools. Variations of these types are where more than one flake has been struck off the same portion of a core, resulting in concavo-convex examples.

Second Early Pluvial Flake Types.

Both Alpha techniques were employed during this period. Flaking lacks finer control and is devoid of finesse. The Alpha Flake is angular and gawky-looking with a prominent backbone and conspicuous lack of symmetry. There is no secondary trimming and faceting of the butts seems accidental or natural. In the specialised Alpha variety a startlingly advanced technique is displayed and the general shape of artifacts is rudely prepared on a hump-backed core prior to detachment. Here there does appear to be a little planned faceting, but still no secondary trimming.

Third Early Pluvial Flake Types.

A noticeable improvement marks artifacts of this age, but it is a simple development of the older techniques and no new innovations have been introduced. The general type of flake is somewhat crude and asymmetrical, with the backbone extremely prominent. But there is a general tendency to produce a wider variety of tools, including pointed forms, as well as slender cutting edges or side scrapers. Sizes are still small, lengths rarely exceeding 3 inches. Islands of cortex often appear, but to a lesser degree than in the former pluvial.

The Alpha technique here assumes a marked degree of development, so a description will not be out of place. At an early stage in the investigation of the old Flake types it became apparent that some of the flakes had been shaped on cores prior to detaching, but the whole idea was so revolutionary that the full import of it was not at first appreciated. This mode of technique we associated with the Levallois, but nobody seriously contemplated a similar prototype in the Pliocene. Since those early days large collections of Alpha cores, both struck and unstruck, have been made from beds of the Third and Fourth Early Pluvials and an accurate idea is now possible of the methods employed. Cores are shaped from angular fragments, are hump-backed like the Levallois "tortoise" variety, about

3 inches long, 2 inches wide, and very thick. The dorsal surface exhibits usually about three flake scars, running roughly lengthwise, or often only two, with a high backbone in the centre. These terminate at the tip in a transverse flake surface which slants downwards from the hump and guillotines the flake when it is struck. At the butt end is the striking platform, either natural or prepared, inclined at a wide angle. Faceting is never elaborate, consisting most usually of a single negative scar, or suitable flat surface in the rock itself. The ventral surface may be natural or artificial, and may assume any shape as this is of no consequence. The flakes which are struck take with them about half of the prepared dorsal surface of the cores. The technique is stone on stone, and bulbs and cones are of normal size. There are no examples of step, hinge, or plunging flakes. Sometimes more than one flake is struck from the same core, the second one being of concavo-convex shape. Flakes from the hump-backed cores tend to be square or rectangular, in contrast to the triangular ones of the simple Alpha. Symmetry is good.

There is relatively little difference between the Alpha of the Third and Fourth Early Pluvials, even though pebble types of that same period show a very marked development. This does not appear to indicate a similar source of origin for the two types. Furthermore, in psychological aspect; the Alpha is so far advanced upon the pebble that association of the two is once more impossible. Pebble workers were plodding away clumsily at crude core types while Alpha craftsmen were using advanced designs, thinking ahead and visualising a stone technique in the third dimension. Pebble man never thought further than the second dimension, and though the difference may be only academic it is nevertheless important. The significance of the Alpha need not be stressed. It is patent that our views on the Levallois require re-orientation, while a drastic change of our outlook on old Stone Age technique is imperative. Range of tools covered in both Pluvials is similar, though the more recent ones show improved finish. Types include side and notched scrapers, blades and backed blades, etc. In the older varieties portions of cortex still persist, but this is rare on those of the Fourth Early Pluvial.

Advanced Alpha Types.

Up till about the last quarter of the Fourth Early Pluvial, the general trend in the flake industries was to produce small artifacts, for man had not yet acquired the art of detaching big flakes. But during the last quarter we see an increase in the size of products. Blades of 6 inches are not uncommon, even though thick and clumsy, while all the time small types were slowly falling from favour. This age of big artifacts is the age

of the Advanced Alpha technique. Butt angles are still wide, faceting limited, and bulbs of percussion of normal prominence.

Proto-Clacton Types of the First Pluvial.

The Advanced Alpha in modified form perseveres into the first phase of the First Pluvial. Here it assumes a Clacton-like appearance with very prominent bulbs and cones of percussion. Platform angles are still at 120 degrees, while faceting of butts grows more lavish. Size of tools is further increased, some blades being 9 inches long and weighing up to 10 pounds. Bulb undersides are not touched and secondary trimming is not popular. But symmetry is good and a wide selection of tools is at hand.

This industry flourished at the same time as the early Abbevillian, and the co-occurrence has been noted by many investigators. Van Riet Lowe calls it the Clacto-Abbevillian group. It is very conspicuous in the oldest "Stellenbosch" of the Cape and in the "Stellenbosch" of the 40-foot Vaal level at Vereeniging. In the eastern Limpopo basin, on the Portuguese East African border, it is equally conspicuous, most notably at Pafuri (9), where it occurs in the surface rubble on the low hills. Here a noteworthy feature is the abundance of artifacts and the giant size of flakes. In parts this rubble is underlain by a white tufa impregnated bed of decomposed volcanics, and from it have been retrieved three badly weathered Developed Pebble specimens. This reaffirms the climatic break between the Developed Pebble and the Clacto-Abbevillian series, as well as indicating the superior age of the former.

There is also considerable evidence of the Clacto-Abbevillian in the Zoutpansberg at Wyliespoort, to the north of Louistrichardt, but here it appears to have undergone slight modifications and to be less well executed.

Rainfall during the Early Pluvials.

A rough determination of pluvial rainfall can be computed from a study of former pan levels, taking into account pan and catchment areas, percentage run off, annual evaporation and permeability factors, and lesser variables. An analysis of the Benoni pan shows that the rainfall during the Fourth Early Pluvial surpassed a maximum of 50 inches—or almost double the present annual precipitation. No figures are available for the other Early Pluvials, but the Pomona pans indicate that they are unlikely to have differed much from these. The evidence does not disclose whether the rainfall was steady or deluge, but Rietvlei points to the latter. It also shows that the Fourth Early Pluvial was of greater intensity than the First Pluvial.

Vaal River Gravels.

For half a century the diamondiferous Vaal gravels have excited public interest. The discovery that they were implementiferous as well post-dates this by barely a dozen years, and many pioneers, including Johnson and Péringuey, were quick to remark on the vast accumulations of cleavers and handaxes. But the full exploitation of the importance of these deposits was left to van Riet Lowe a long while later. For the past twenty years he has been collecting from the gravels of the lower terraces, at Shepherd Island, Bloemhof, Vereeniging, Riverview Estates, Windsorton, etc., and from the Riet and Klip tributaries. The results have had a profound effect on South African prehistory, and the trend of the current investigations seems to indicate that the Vaal is likely to continue to dominate all other theatres. Van Riet Lowe originally only worked on the lower terraces, but the higher ones are now proving of equal value in the pre-palaeolithic sphere. He had previously only found artifacts as far up as the top of the 60-foot terrace at Riverview Estates (8), but he and Breuil are now collecting from a 150-foot level, as well as from intermediate ones. The earlier artifacts are undoubtedly Kafuan or Earliest Benoni Pebble in facies.

Du Toit is collaborating in much of this investigation, and has expressed the opinion that the high terraces of older Gravels are not indicative so much of higher flood levels as of a series of crustal warpings (10). With this the writer is in agreement, for the presence of Tertiary and post-Tertiary earth movements is firmly established (4). The gravel beds of these elevated terraces (there are ones well above the 300-foot level) are thin and cover great areas, giving the impression of being land surface erosion beds on a series of old plateaux, rather than conventional terrace deposits. Yet it is patent that they indicate not only crustal distortion, but increases in precipitation as well, and are probably counterparts of the Early Pluvial beds of the Witwatersrand pans.

Below are appended a few notes on the Vaal-Witwatersrand correlations. These are tentative and reflect merely the personal views of the writer. The Bureau of Archaeology will, doubtlessly, in due time, publish an authoritative report on the work there. In the Vaal theatre considerable confirmation of pan data is available, and though the corroboration is often incomplete, it is interesting to note that nothing occurs to contradict pan-based conclusions. The pre-palaeolithic Vaal collection is of fair proportions and wide diversity. Classifications, however, cannot be made on purely geological lines, for the gravel beds all formed old land surfaces and their contents were partially accessible to man of the various ages, who mined and used these pebbles. But the employment of all available methods permits satisfactory groupings.

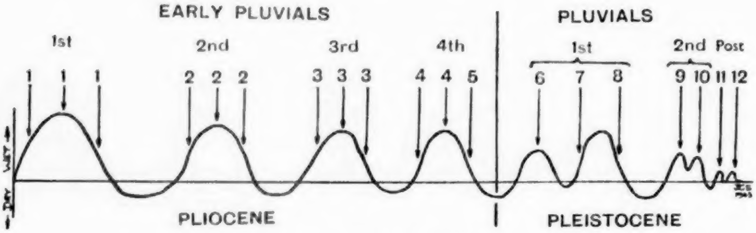
There is evidence in the Vaal basin of at least three (probably four) of the writer's Early Pluvials, and all his early types of artifacts are represented. The 50-foot terrace of older Gravels at Vereeniging, which yields Clacto-Abbevillian or Vaal-Stellenbosch I types, is obviously the contemporary of Part I of the First Pluvial. The 100-foot terrace at the same site, which spreads out plateau-like, yields Third and Fourth Early Pluvial type artifacts in an unworn state, and worn ones derived from some previous wet period. The bed therefore had its origin in the Third Early Pluvial, was mined and exploited during the Fourth Early Pluvial, and the Second Early Pluvial types were derived from the previous wet phase or Second Early Pluvial. This latter wet phase has not yet been located anywhere as a geological bed. A number of re-worked specimens indicate considerable differences in age. The 150-foot terrace of Windsorton yields the oldest series from the Vaal. The forms represented are typically split pebble, and very reminiscent of Wayland's Kafuan. They duplicate the series of First Early Pluvial age from Pomona Estates. The entire Vaal assemblage is very interesting and comprises both core and flake types.

Pre-Palaeolithic Types of Rhodesia.

Rhodesia has not yielded much of importance so far. That may come with more systematic investigation. The three discoveries of interest are: (1) Neville Jones's Hope Fountain, described by the discoverer as pre-Chellean (11). Breuil bears out the writer's views that this is not a satisfactory industry. It is a jumble of various types and ages, and it is doubtful if the oldest components are of any considerable antiquity. All appear more recent than the Advanced Benoni Pebble. (2) Leslie Armstrong, while investigating the Zambesi gravels at the Victoria Falls (12), located old Hope Fountain types in the gorge well below the present falls, which are geologically older than the normal handaxe group. These, too, are more recent than any subdivision of the Benoni Pebble. The discovery is of interest in that it indicates that deposition took place during a wet climatic phase. (3) The final site of importance is in this same neighbourhood, in a nearby railway cutting, and has been described by Maufe (13). The paper is on the stratigraphy of the Kalahari beds, and has an interesting bearing on the past climates of Southern Africa. He correlates his observations with those of Passarge in the Kalahari and Veatch in Angola and the Gold Coast, and stresses the marked similarity of beds throughout this area. The climatic inferences to be drawn from this table is that there were probably three climatic oscillations during the Pliocene. Some of the beds appear to contain pebble type tools. In a subsequent paper on the Falls area (14), Cooke and Clarke describe a series of Abbevillian

and later types with reference to Maufe's strata. A tabulated graph is included, showing the relation between former climates and artifacts.

TRANSVAAL HIGHVELD PLUVIAL CURVE AND ARTIFACTS



Note: Curve not to Scale.

1. Earliest Benoni Pebble Culture.
2. Early Benoni Pebble and Early Alpha.
3. Later Benoni Pebble and Alpha.
4. Developed Benoni Pebble and Alpha.
5. Advanced Benoni Pebble and Advanced Alpha.
6. Advanced Alpha, Earliest Abbevillian, and Proto-Clacton.
7. Early Abbevillian.
8. Acheulean and Lower Levallois.
9. Mid Levallois and Advanced Acheulean (Early Middle Stone Age and Fauresmith).
10. Advanced Levallois + (Late Middle Stone Age and Early Smithfield).
11. Late Smithfield and Wilton.
12. Bush and Bantu.

Fig. 2.—Pluvial curve for Transvaal Highveld and associated types of Artifacts.

East London Clays.

In 1935 McFarlane published a paper on the pre-Stellenbosch types of the East London clays (15). The issue is somewhat confused, for the pebble horizon is not sharply defined and tools of Stellenbosch (unworn) and pebble (worn) age occur mixed together. Judged by the specimens in the Bureau of Archaeology, the collection is not convincing and not Benoni Pebble in facies. Tools are very small and very crude.

Relative Ages of the Various Types.

There is, admittedly, no foolproof geological or other means of determining the age of deposits. But there are numerous ways of establishing rough approximations, and if we use a diversity of methods, a rough point of convergence is established which gives a reasonably fair indication. Let us apply this principle to the pan deposits.

(1) The geological approach can only be along the lines of Croll's hypothesis, where account is taken of the relative thickness of strata. This hypothesis may only be applied, strictly speaking, to the thick accumulations and vast time periods that mark the milestones in geological

history, but their application to the Pliocene and Pleistocene pan deposits does give some rough idea of relative durations. No more is claimed for it than that. When applied to the pan beds the following conclusions are indicated: that the pluvial curve for the Highveld is a diminishing one on the time scale, if not on the intensity scale as well. The First Early Pluvial was of longest duration, and thereafter Early Pluvials appear to have grown progressively shorter, diminutions in each case averaging about 20 per cent. It follows, therefore, that the First Early Pluvial endured almost twice as long as the Fourth.

On the intensity of pluviation scale there appear to have been marked diminutions as well, though these were not necessarily proportional or progressive. However, it may safely be assumed that the older pluvials were wetter than the more recent ones and rainfall possibly more concentrated.

(2) Another facet of approach is by a study of abrasion and patination. The two are somewhat inseparably related, for abrasion tends to be more rapid in patinated, weathered, or chemically altered rocks. As exposure to the elements expedites both processes, comparisons of rocks on the surface are not permissible with deeply buried and sheltered ones. But if, however, rocks are of the same mineral group and we feel that conditions which controlled their past histories were similar, then there is justification for rough comparisons. Pan beds, we feel, come under this category. Comparing the degree of abrasion of artifacts from various pluvial ages, the conclusions drawn are that each particular group of artifacts is of considerably greater age than the group which succeeded it.

(3) If we compare the degree of abrasion of surfaces in artifacts that have been worked in two separate periods, we find that these reworked specimens indicate that the period which separates the two series of chippings often appears to have been longer than the time which has elapsed since the last chipping, even though this took place during adjacent pluvials. Numerous such reworked artifacts are available and all stress this point.

The general conclusion to be drawn from the above appears to be that old pluvials were of longest duration and that succeeding ones grew progressively shorter.

We have now established a law of variation, but we still have to establish a starting-point before any age estimations can be attempted. Let us see if it is possible to date the Fourth Early Pluvial. Here we have three lines of approach:

(1) *Climatic.*—The Fourth Early Pluvial preceded the wet period which tided in the Abbevillian. If we assume synchronised palaearctic glacials in Europe and pluvials in Africa, it is probable that this pluvial was of latest Pliocene age.

(2) *Geological.*—If we are right in assuming that the Kalahari red sand period separates the Pliocene from the Pleistocene, then the Fourth Early Pluvial once more stamps itself as of late Pliocene age.

(3) *Typological.*—There is no reason whatever why Benoni Pebble types could not be of Pliocene extraction. In fact, the typological evidence for such an origin is very convincing.

The general conclusion upon the consideration of these three points is that the Fourth Early Pluvial was of at least Plio-Pleistocene transitionary age, if not late Pliocene. This is not in accordance with Wayland's views, for it would appear that he pushes back the Pleistocene at least another two pluvial phases (16). No matter in what light we consider the problem, it is patent that the First Early Pluvial must be well back into the Pliocene. Breuil, too, seems satisfied that the artifacts from the 150-foot Vaal terrace are of Pliocene age.

It is difficult to compute the duration of the inter-pluvials for there is little tangible evidence to work upon. Geological evidence is inconclusive, yet it is suspected that as they were part of a symmetrical climatic curve they probably varied in proportion to the adjacent pluvials. If that were so, then it is probable that they were governed by the same principle of diminution as the pluvials.

Nor is it a simple matter to determine the degree of desiccation during the dry periods. The formation of ferricrite, like tufa, varies under different conditions, poor underground drainage being conducive to the growth of ferrous impregnations at relatively high rainfall figures. But in well-drained soil it may generally be said that ferricrition is indicative of lower, and probably more seasonal, rainfall than obtains at present. The indications on the Witwatersrand are that these dry periods followed no fixed laws of variation, but that all were relatively dry, some more so than others.

The red Kalahari sand period is not actually represented at Benoni, but on the Vaal River it overlies the 60-foot terrace at Riverview Estates, in the top portion of which Developed Benoni Pebble types are found. This stamps it as the dry period which succeeded the Fourth Early Pluvial, evidence confirmed by the Rietvlei beds, but not at Benoni.

Vereeniging Pan.

Some few miles to the south of Vereeniging, along the old Parys road, there is a very deep and conspicuous pan off to the west, designated "Vereeniging Pan" on some maps. A series of extensive excavations dot the rim of this pan, and from these an interesting collection of pebble and Flake tools was made. The investigation of the site was unfortunately

hurried, but it is patent that artifacts of probably three Early Pluvial ages are represented. Classification is possible not only on typological grounds, but on the gradations of abrasions and on the adhesion of hard calc tufa to the older specimens. The tufa is evidence of a breach in pluvial conditions and appears to represent the dry period between the Third and Fourth Early Pluvials.

Wellington, Cape.

In the vicinity of the Wellington town reservoir, to the east of the town, numerous deep excavations have been made for gravel. From the sides of these, well below the pebble erosion bed of Stellenbosch age, a few Developed Benoni Pebble and Alpha Flakes were collected, typical of the Witwatersrand Fourth Early Pluvial ones. The Table Mountain sandstone from which they were constructed was so badly decomposed and so deeply impregnated with the clay of the bed from which they were extracted, that it was difficult to detect them. Artifacts here are so rare that a long search realised only a dozen. At other quarries to the N.E. along this high ground, more specimens were collected from some feet down in this same clay bed, well below the erosion strata containing Acheul Stellenbosch types. From the pebble-gravel bed in the orchards above the Hawequa River, a mile north of the railway station, numerous Clacto-Abbevillian types were found. They are from the same horizon as the later Stellenbosch ones, but more heavily rolled and decomposed, and obviously of greater antiquity. Typologically they belong to the First Pluvial, Part I, whereas the Acheul Stellenbosch was only deposited on this old land surface during the Second Phase of this pluvial. At all events, the presence of pebble and Flake types in the Cape is firmly established.

Conclusion.

The period covered in this paper is considerable. It commences in the Pliocene with some of the earliest stone relics fashioned by primitive man, and terminates with the advent of the Abbevillian. This epoch has been appropriately called the "Pre-Palaeolithic" and is little known and not much studied, for it is thought to lie beyond the limits of sound reasoning. The narrative has been approached along orthodox lines, but as parts of the substance are new to archaeologists, it has been necessary to go into some detail. That has been unavoidable. Prehistory is not a pure science: it is one compounded from fragments of many branches of science. Artifacts are bound up intimately with strata, strata with geology and palaeontology, and geology with past climates. These and other allied sciences thread their way inseparably through the picture, and form a fitting background to primitive man and his artifacts.

It has been endeavoured to present problems in such a fashion that readers can draw their own conclusions. A few broad principles, however, stand out with great clarity:

(1) The Stone Age in South Africa is of great antiquity.
(2) The early phases are more complex than is generally believed.
(3) It is by no means devoid of interest.
(4) Considerable development had been attained by man at a very early age.

The question of whether Benoni tools are in direct line of ancestry to the handaxe is not really relevant to this paper, but it is the belief of the writer that such is the case, for the chain from the Earliest Benoni to the end of the Abbevillian shows no interruptions or discontinuities. Van Riet Lowe has previously hinted at this possibility (18). Taking into account the fact that South Africa has larger concentrations of the early lithic cultures than any other country, the indications are that the sub-continent has fair claim to have been the centre of origin of stone culture, and that it may thus well have been the cradle of the human race as well. This archaeological data, together with a growing mass of palaeontological evidence, gives Africa a useful lead over Asia or any other continent.

The distinguished chronicler Herodotus did well to warn us two thousand years ago to expect strange things of Africa. Let us heed this good advice, and, while striding forth boldly, let us exercise reasonable caution and avoid hasty conclusions. The large simians, quite unknown to Europe, that made such an impression on the early explorers of our continent, still survive in the forests of the Belgian Congo to-day. The mastodon, that perished before the Pleistocene Ice Age in Europe, is found mixed up with Acheulean man in the Transvaal, and Lang goes so far as to claim that it is even depicted on rock engravings of the Middle Stone Age. Advanced anthropoids roamed the flat plains at Taungs, or the escarpment at Strekfontein, when Stone Age man was fast approaching the status of Homo sapiens (19). Though exiled to the Kalahari, the primitive little Bushman still survives after his decisive clash with modern civilisation.

The problem of the correlation of the lithic cultures of Africa is one that involves, to a considerable degree, questions of geographical orientation. We are apt to forget that the present international frontiers did not obtain during the Stone Age, and that man was not provincial or national minded. Topographical barriers did exist, but these merely delayed and did not exclude permanently. So we must hesitate before discriminating between East, North, or South Africa. Let us rather consider the Pre-Palaeolithic as a great all-embracing project in human history, that had partiality for neither country nor clime, but that swept on steadily and inexorably, with the pulsations of evolution.

ACKNOWLEDGMENTS.

The writer would like to acknowledge his sincere gratitude and thanks to the following : Professor van Riet Lowe for advice and assistance, for communicating this paper and for help in many ways; the Abbé Breuil for his seasoned advice and for permission to quote from private correspondence; and Dr. A. L. du Toit for his generous assistance, especially relative to the publication of this paper.

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JOHANNESBURG,
15th June 1943.

EXPLANATION OF PLATES.

Plate I. Fourth Early Pluvial Artifacts.

10. Developed Benoni Pebble type side (core) scraper on natural cleavage base with secondary trimming. Basal chipping done subsequent to completion of peripheral flaking.
11. Similar to 10. On prepared negative bulb face.
12. Similar to 10. Base initially flat part of pebble itself.
13. Similar to 10 in all respects.
14. Lower Benoni Pebble type "ripper" from base of pluvial. Note rostrocarinate shape.
15. Lower Benoni Pebble type "slicer" or long cutting edge. Note rostro shape.
16. Borer or pointed pebble of early pluvial age.
17. Struck Alpha core. Two views.
18. Unstruck Alpha core.
19. Round stone or bolas.

111, 112, 113. All Alpha types. Note wide platform angle and absence of trimming.

114. Unstruck Alpha core (two views). Note similarity of Alpha technique to the Levallois.
115. Unstruck Alpha core.
116. Struck Alpha core.

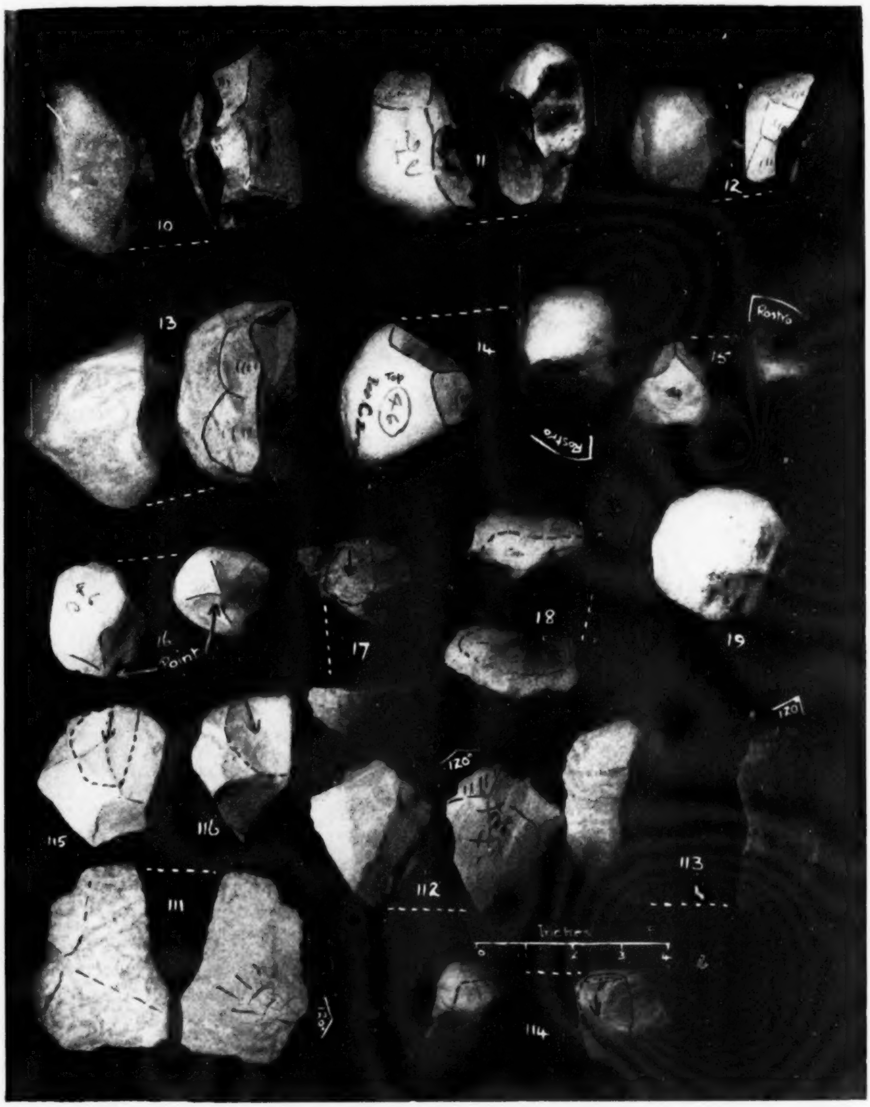
Plate II. Third Early Pluvial Artifacts.

22. Crude Later Benoni Pebble type "ripper." Two views of ripper edge.
23. Later Benoni Pebble type side (core) scraper. Positive bulb base. Note steep peripheral chipping.
27. Simple Later Benoni Pebble "split pebble" type. Split by single blow. Not known whether implement or discard type.
28. Split pebble type. Two blows.
29. Unstruck Alpha core (two views). Note unprepared platform and obtuse angle.
213. Similar to 29. Platform prepared by single blow.
210. Round stone or bolas.
211. Alpha type. Rude construction. Concavo-convex.
212. Alpha type. Two views. Note simplicity.
214. Similar to 212, but slightly older.
215. Similar to 211. More advanced.
217. Similar to 215.
21. Developed Benoni Pebble type side (core) scraper on natural cleavage base. Note steep peripheral chipping. Subsequent trimming of base.
24. Similar to 21. On prepared negative bulb base. Base prepared prior to peripheral chipping.
25. Similar to 24.
26. Similar to 24. Whole base negative bulb surface.
216. Alpha Flake type. Secondary trimming very rare.

PLATE III. FIRST AND SECOND EARLY PLUVIAL ARTIFACTS.

31 to 33 are of Second Early Pluvial age. 42 to 47 are of First Early Pluvial age.

33. Crude Early Benoni Pebble type side (core) scraper. Platform flat natural pebble surface.
32. Alpha Flake type of Second Early Pluvial age reworked during the Third Early Pluvial. Badly worn and decomposed. Platform prepared by single flake. Largest Alpha specimen known from this age.
31. Similar to 33. Natural (thermal) cleavage base.
42. Crude type of Earliest Benoni Pebble side scraper, very similar to split pebble. Base is natural flat pebble, under-side with three very steep edge flakes. Somewhat worn.
43. Similar to 42. Flaking not so steep.
44. Cutting instrument constructed on a positive bulb base. Flaking at flat angle. Worn.
45. Notched scraper constructed on a positive bulb base. Badly worn.
46. Double notched scraper on a flat slab-like piece of stone. One notch constructed by single blow, the other by two blows. Unworn.
47. Notched scraper. One notch conspicuous—bordered by a series of small notches, forming a serrated edge. Worn.



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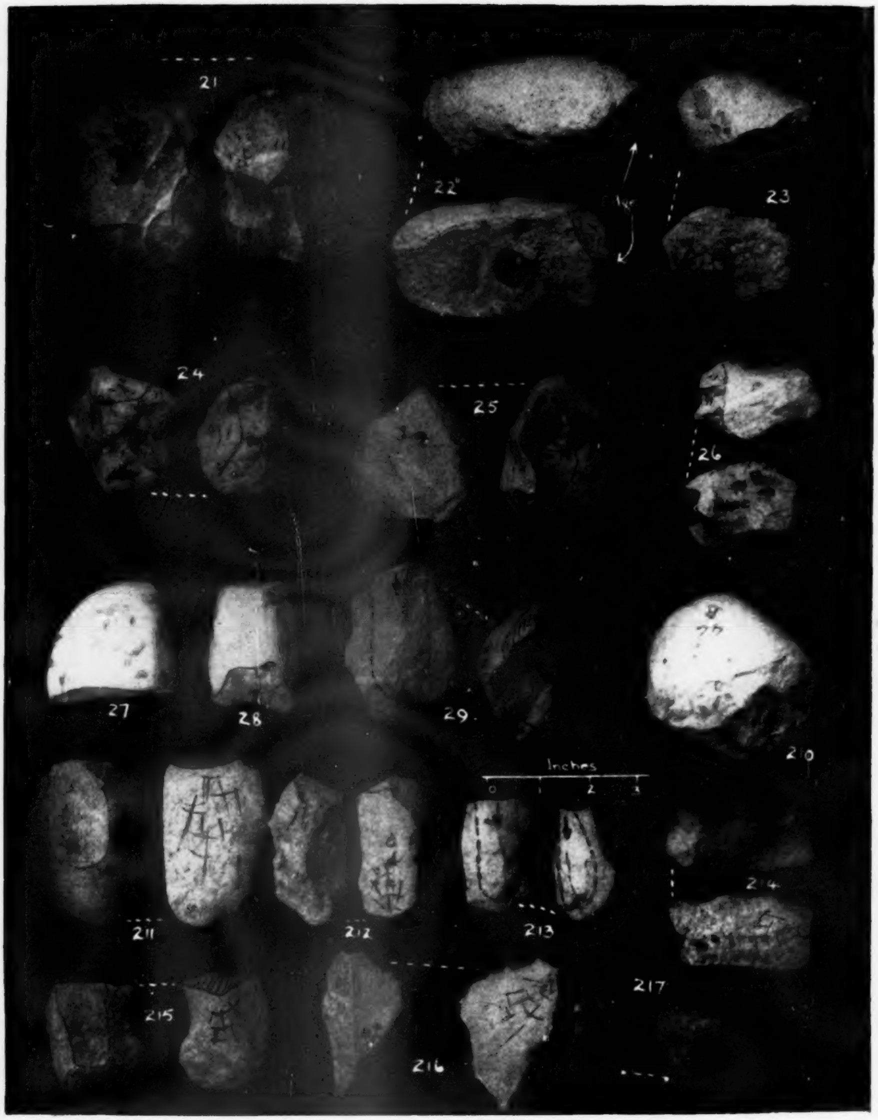

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STONE IMPLEMENTS OF THE EASTERN LIMPOPO BASIN.

By J. C. Smuts, Jun.

(Communicated by C. van Riet Lowe.)

(With Plates IV–VIII.)

(Read October 13, 1943.)

South African prehistory is characterised by a wide diversity of rather unusual types, and in the Eastern Limpopo basin this characteristic is even more accentuated than elsewhere.

In 1928 the writer made a collection of stone implements from the Limpopo basin at Pafuri, Portuguese East Africa. This collection has on several occasions been considerably augmented, and now represents an interesting and unusual assemblage, full of new and strange features. The Abbé Breuil, when in this country in 1929, was much interested in this collection and remarked that he would divide it into three typological groups. Professor van Riet Lowe has repeatedly remarked that he considers this one of the most interesting of collections.

Some years ago the writer prepared a paper on the Pafuri artifacts, but this was fortunately never released, for since then much new information has come to light. Many points of difficulty have been simplified and a chronological background has been established. Until quite recently there was the tendency to regard the assemblage as a blending of influences, partly Abbevillian and partly old Clacton. However, from information recently obtained on the Transvaal highveld from Benoni and near Pretoria, it would appear that some of the Pafuri types flourished before either a true Abbevillian or Clacton had materialised, so that many of the earlier conclusions perforce suffered a complete metamorphosis. The new rough determination of age has merely added to the interest and importance of this collection.

The Pafuri Site.

The Limpopo basin is one of the topographical features of the Northern Transvaal, for it constitutes a vast trough-like hollow worn into an otherwise flat lowveld. At the Portuguese border it attains a width of over a dozen miles, the sides shelving down rapidly in the form of a small escarpment a

few hundred feet in elevation. The type site is at Pafuri, a recruiting outpost for mine natives, just beyond the limits of the Kruger National Park at the Pafuri-Limpopo confluence. It is in the centre of this great basin, and here and there an occasional low ridge or koppie breaks the monotony of the wide bush- and grass-covered Limpopo flats. The koppies apparently owe their origin to some remote pluvial phase, for they consist simply of great mounds of Karroo Age conglomerate covered with pebbles, sands, and grits.

These koppies and ridges are the centre of the lithic industries, and the pebbles were used in the manufacture of the implements. Pebbles occur in all shapes and sizes, rendering core or flake techniques optional. At the central site at Pafuri at least 20 per cent. of exposed rocks appear to have been tampered with by primitive man, though both eastwards and westwards this figure decreases considerably. Implements have been traced by the writer for 10 miles up the Pafuri River into the Kruger National Park, and for about 50 miles east of Pafuri, opposite Mapai on the Limpopo, and over the entire distance of 60 miles they persist with remarkable regularity and in considerable quantities. There can be little doubt that the distribution of artifacts must extend far beyond these bounds, which merely represent the limits of exploration.

Investigation of the site at Pafuri was on all occasions hurried and consequently somewhat superficial, only surface products being picked up. Artifacts are mostly of very generous proportions and it only takes a few to fill the back of a car. From the present knowledge of the site it is impossible to cast any direct light on the geological age of the implements. Nor is it possible to state the relation in age between artifacts and koppies, though it is evident that the koppies are of much greater antiquity than the human products. Tools are somewhat fresh and unworn in appearance, ruling out extensive transportation or shuffling by water action. Many specimens have suffered badly from the ravages of veld fires and have been much disfigured by thermal fractures.

The most obvious feature of the pebble-covered koppies is that we are dealing with the debris of hillsides that have been undisturbed land surfaces for a very long period. Hence we find abundant evidence of artifacts of various ages and cultures jumbled together into one heterogeneous mass. A further point to be noted about this Pafuri area is that it is both a factory and a home site, so that we can not only study the various techniques from discards, but also have the evidence of the finished or end products. Here it may be added that it is often difficult to distinguish between the end products of earlier industries and the discards of later ones. There is sufficient evidence, however, to enable positive discrimination.

General Features of Implements.

In many respects this paper is a sequel to two others which have already appeared and in which the earlier cultures have been studied and described. It is not here deemed necessary to give a recapitulation, and the reader is referred to these works (1).

Two things immediately strike one in walking over the site at Pafuri: the general crude nature of the assemblage and the vast size of the implements. This applies to both core and flake types. Concerning the latter, it may be said that this type is characterised by the simplicity as well as by the crudeness of the flakes. Judging by the proportions of artifacts, the makers must have been gifted with great ingenuity and abnormal strength. Bulb underfaces are seldom touched and secondary trimming is never extensive. Striking platforms are sometimes natural, sometimes prepared by a single blow and equally often by two or three blows, but marked faceting is never evident. Platform angles are wide and bulbs most conspicuous.

Core types are characterised by flat basal planes (or platforms) with steep peripheral flaking, such as is to be found in advanced pebble assemblages.

Classification of Implements.

Emphasis has been laid on the fact that the assemblage is in no way simple or homogeneous, yet it may be described in general fashion as being of Pre-Stellenbosch or Pre-Abbevillian age, though there are a few later admixed elements. We are already aware of the presence of both core and flake types, but the classification may be taken even further than this. Stratification is nowhere conspicuous and patination offers no solution, hence all differentiations must rest on a typological basis. In this we are aided by the marked contrast in appearance of the various types.

As a working hypothesis the following divisions may safely be adopted (arranged in approximate chronological order):—

5. Abbevillian.
4. A specialised "Flat" Abbevillian.
3. Proto-Clacton primitive Flake.
2. Advanced Benoni Pebble types.
1. Developed Benoni Pebble types.

Let us consider each group in more detail.

1. *The Developed Benoni Pebble Group.*

This is represented by a pair of much worn badly decomposed specimens which are obviously of much greater antiquity than any of the other tools

of the assemblage, both on appearance and on stratigraphical grounds. They were extricated from a calcrete bed in a road cutting two-thirds of the way up the main hill at Pafuri, the calcrete overlying bedrock and underlying the pebble bed of the other cultures. The technique is typically Developed Benoni Pebble—base prepared by a single blow and steep flakes struck from this base, flaking occupying less than half of the periphery. Both are constructed on flat oblong water-worn pebbles. It is obvious that these tools must precede the four other Pafuri groups by a very considerable period. See Nos. 10, 11.

2. *The Advanced Benoni Pebble Group.*

Tools are constructed on pebbles, pebble splinters, and such-like suitable forms; chipping is steep, crude, and uncontrolled. Chronologically this group is still Pre-Stellenbosch, though an ancestral form of handaxe had already appeared. Indeed, it is the most typical tool of this period at Pafuri. The powerful influence of the pebble technique has only been partly cast off, for flaking is still predominantly steep and peripheral. Edges are markedly zigzag and very jagged. Symmetry is poor and few handaxes are at all sharp at the tip, mostly ending merely in chisel points. See Nos. 47, 48, 50, 51.

3. *The Proto-Clacton Group.*

Initially the writer considered the influence in this group as early Clacton, but there is now reason to believe that the Clacton appeared only some while after these prototypes: hence the name "Proto-Clacton." Strictly speaking this type is merely a form of Advanced Alpha Flake, but because of the very conspicuous or "brutal" bulb it has been designated a Clacton affinity.

Platform angles are generally at 130 degrees, and the undersides of tools are constituted by plain bulb surfaces with the bulb usually at the butt end of tools. It follows that all Proto-Clacton tools are unifaces.

All tools of this group are noteworthy for their extreme simplicity of design. There is no elaborate chipping of a fine nature. Tools are characteristically large, and only a few big, flat, flakes are struck. Secondary trimming is not always resorted to, but when employed it is only of a rough slipshod nature and completely devoid of any finesse. In the true Alpha culture there is no secondary trimming whatever. Only in rare instances at Pafuri was any attempt made to obliterate the bulb protusions by chipping, and in only one type of tool is the bulb side of tools tampered with by being faintly trimmed round the edge.

There are four general types of tools in this group:

(*a*) Blade-like handaxes (see Nos. 53, 54, 55, 30, 31).
(*b*) Giant Crescent Choppers (see Nos. 28, 29).
(*c*) Simple cleavers (quite unlike Stellenbosch ones; see Nos. 56, 58, 59, 60).
(*d*) Small flake side scrapers (the only small Pafuri tools; see Nos. 32 to 35).

Handaxes are not almond-shaped or pointed but distinctly oval. Flaking is usually longitudinal and flakes are of a flat generous nature. The crescent chopper is probably one of the simplest and most effective products of the lithic world. It is constructed by striking a large thick semi-circular flake off the side of a flattish pebble. The crescent edge is trimmed all the way round on the bulb side by a series of medium-sized flakes, which, considering the fact that they are secondary, are distinctly crude. Cleavers show a fair amount of variation, but all have fairly broad chisel points entirely devoid of trimming.

The Pafuri craftsmen did not take kindly to small flakes. The few examples, however, display the same characteristics as the larger ones, showing that the technique is perfectly standard.

4. *The Specialised Abbevillian Group.*

Professor van Riet Lowe describes the handaxes of this series as fairly typical of the Abbevillian, yet the writer is inclined to consider them as representing a slightly older age—possibly some closing stage of the Advanced Pebble era. Whatever the case, it would be safe to describe them as at least early Abbevillian.

The normal Abbevillian handaxe is a tool that is constructed on fairly thickish pebbles, but in this specialised group we have a handaxe technique applied to a flattish pebble. There is yet another distinctive feature which will later be stressed.

This handaxe is one of the commonest and most conspicuous tools of the Pafuri site and the technique throughout is perfectly standard. Tools are fashioned on flattish oblong pebbles of almost suitable shape and size, and chipping is confined to the front part of pebbles. Butt ends remain untouched, the smooth surface affording a convenient grip for the hand. Tools are all bi-faces. On one face flakes are struck off roughly longitudinally with the long axis forming a flat sort of platform running half the length of the tool. Then utilising this flat prepared platform, a series of steep flakes are knocked off the upper face, the scars this time running transversely to the long axis. The resulting handaxe is almond-shaped in plan, but beaked in side elevation, much like the prow of a boat.

The writer believes that this specialised form well deserves the space

devoted to it in this article, not only because of the methodical nature of technique or of the strong Advanced Pebble affinity, but also because it apparently appears nowhere else in Africa. It is thus possibly a very limited, or even local, variation. See Nos. 43 to 46.

5. *The Abbevillian Group.*

Tools of this division hail, typologically, from the lower Abbevillian. Handaxes had already assumed a true symmetrical shape. Specimens are still clumsily flaked though more refined than their precursors. This was the critical stage at which the characteristic steep flaking of the Benoni Pebble age was being displaced by a newer flatter system of flaking. The result is not entirely satisfactory for specimens are badly disfigured by step flakes and blemishes. Both oval and pointed handaxes occur and all are unduly thick in cross-section and irregular of edge. See Nos. 41, 42, 49, 51, 57.

Age of the Various Types.

As previously stated, classification rests not upon stratification or patination, but purely on deduction. Now it so happens that at Rietvlei, near Pretoria, tools bearing a striking resemblance to the Pafuri Proto-Clacton type have been found stratified at the extreme base of the First Pluvial period. In the same horizon are also a few Advanced Pebble specimens, so that the contemporaneity of the two types is fairly firmly established. The commencement point of the Abbevillian is in the vicinity of the 30 per cent. mark of the First Pluvial period. The flat Abbevillian does not occur at Rietvlei, but is probably to be associated with the commencement of the same pluvial.

Implements of Chiquala-Quala, 35 Miles East of Pafuri.

This site is situated some 35 miles S.E. from Pafuri, 10 miles above the confluence of the Uanetzi (Nuanetsi). With this locality the writer is well acquainted for he has on numerous occasions hunted here. The low plateau separating the two rivers narrows down into a solitary ridge of hills which finally peter out 2 miles from the confluence. The high plateau which flanks the northern bank of the Uanetzi comes in closer and shelves down rapidly to the Flats in a series of badly eroded undulating foothills. These appear to be remnants of a Tertiary peneplane that once filled in the entire Limpopo-Uanetzi basin. The upper portion, possibly over a hundred feet in thickness, appears to be of Pliocene and Pleistocene origin.

Chiquala-Quala is 350 feet above sea-level and about 300 miles from the East Coast, and here we have the same topography, brought about by the same conditions, as at Pafuri, so that we naturally expect to find similar

types of implements as well. Such indeed actually proves to be the case, but only with modification:

(*a*) The Proto-Clacton type, which is the most conspicuous feature of Pafuri, occurs only on rare occasions, and even then the few representatives lack the immense proportions of the Pafuri ones. See Nos. 1, 6, 9.

(*b*) Almond-shaped handaxes became fairly common though they are of crude execution. These are best described as being less Abbevillian than Stellenbosch in appearance. Nothing quite like them have been found at Pafuri. See Nos. 2, 3, 7, 8.

(*c*) For some obscure reason all tools at Chiquala are markedly smaller.

(*d*) The Benoni Pebble affinity increases at Chiquala.

Conclusion.

The Benoni Pebble Cultures have a very wide distribution in Africa, ranging from the Cape to Uganda, hence there is nothing exceptional in their occurrence at Pafuri. The Proto-Clacton type appears to have enjoyed great popularity at Pafuri, and it seems that this might have been an early centre of evolution. A few stray specimens have been collected at Rietvlei (see Nos. 18 to 23) and near Louis Trichardt (see No. 16), and this at least shows that it was not a completely isolated industry.

At the northern exit of Wyliespoort, in the Zoutpansberg, a very primitive industry occurs which has many elements reminiscent of Pafuri. Evidence for detailed comparison is, however, incomplete, but it is patent that the resemblance is closer than with any other South African type.

We have in this paper discussed a series of core and flake types, but have made no attempt to determine or define their relationship. The various groups have all been discussed as separate entities, yet it must be added, in fairness, that this is only a personal view of the writer. There is no doubt that according to the majority of authoritative African prehistorians only two groups will be recognised—the Lower Benoni Pebble and a later group. This is a problem that can only be solved by careful study and excavation.

Acknowledgment.

The writer is sincerely indebted to Professor van Riet Lowe for communicating this paper to the Society and for valuable help and advice.

Reference.

(1) Smuts, J. C., Jun.: "Past Climates and Pre-Stellenbosch Stone Implements of Rietvlei (Pretoria) and Benoni," Trans. Roy. Soc. S. Afr., vol. 25, 1938, pp. 367–388.

EXPLANATION OF PLATES.

Plate IV. Pafuri Implements.

48, 50, 51. Advanced Benoni Pebble types.
43 to 46. "Flat" Abbevillian forms.
52. Unstruck Alpha core.
47. Advanced Benoni Pebble type on natural base (ventral surface).
49. Crude Abbevillian type of coarse conglomerate—probably not as old as other Pafuri types.
50, 51. Elementary handaxes. Note original cortex surfaces.
53, 54, 55. Proto-Clacton type handaxes. Flat flaking and prominent bulbs.
58 to 60. Proto-Clacton type cleavers.
57. Rare Abbevillian type handaxe. Ventral surface disfigured by thermal fractures.

Plate V. Pafuri Implements.

24 to 31. Proto-Clacton types.
24 to 27. Side scrapers.
28, 29. Crescent choppers. Note trimming of edge on bulb side.
30, 31. Handaxes. Note simplicity.
32 to 35. Small Proto-Clacton type scrapers, etc.
37, 40. Proto-Clacton type cores.
36. More recent old Levallois type core (struck).
38. Unusual Proto-Clacton type core (struck).
39. Unusual Proto-Clacton core, reminiscent of the Victoria West technique.
41, 42. Abbevillian type handaxes.

Plate VI. Implements from other Sites for Comparison.

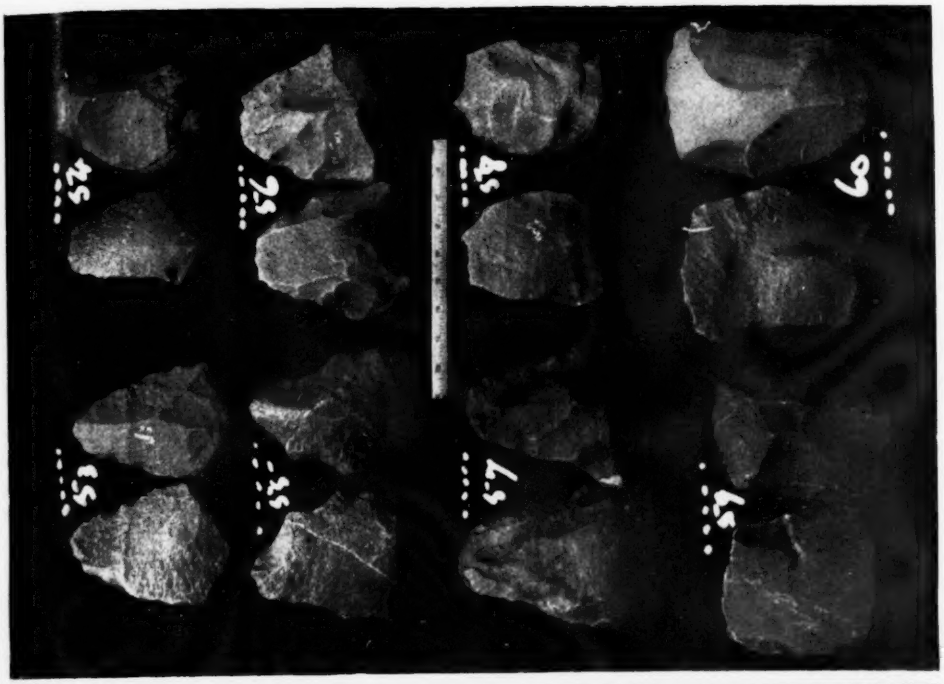
10, 11. Two old, much worn and decomposed Developed Benoni Pebble type tools from the calcrete bed on the main hill at Pafuri.
1 to 9. Tools from Chiquala-Quala, 35 miles away.
2, 3, 9. Proto-Clacton types.
4, 5. Advanced Pebble types.
7, 8. Abbevillian types. 8 has strong Clacton influences.
12 to 14. Tools from Wellington, Cape.
12. Advanced Alpha Flake. Worn.
13. Developed Benoni Pebble type. Worn. Reworked.
14. Clacton type.
15 to 17. Series from Wyliespoort, Northern Transvaal.
15. Advanced Pebble type.
16. Proto-Clacton type.
17. Early Abbevillian type handaxe. Rare.
18 to 23. Series from Rietvlei, Pretoria.
18. Proto-Clacton handaxe from base of First Pluvial period.
21, 23. Advanced Alpha type handaxes from late Fourth Early Pluvial period.
22. Proto-Clacton type from late Fourth Early Pluvial period.
19, 20. Advanced Alpha types from middle of Fourth Early Pluvial period.
1, 6. Clacto-Acheulean types of post-Pafuri age.

PLATE VII. MAIN HILL AT PAFURI.

About 150 feet in height, and typical of almost any of the numerous ones which stud the Limpopo basin. The boulder talus is clearly visible in the photograph and covers the whole hill.

PLATE VIII. THE LIMPOPO FLATS.

The hills are plainly seen to constitute some former high terrace to the river. The Pafuri Hill can be seen in the right distance.



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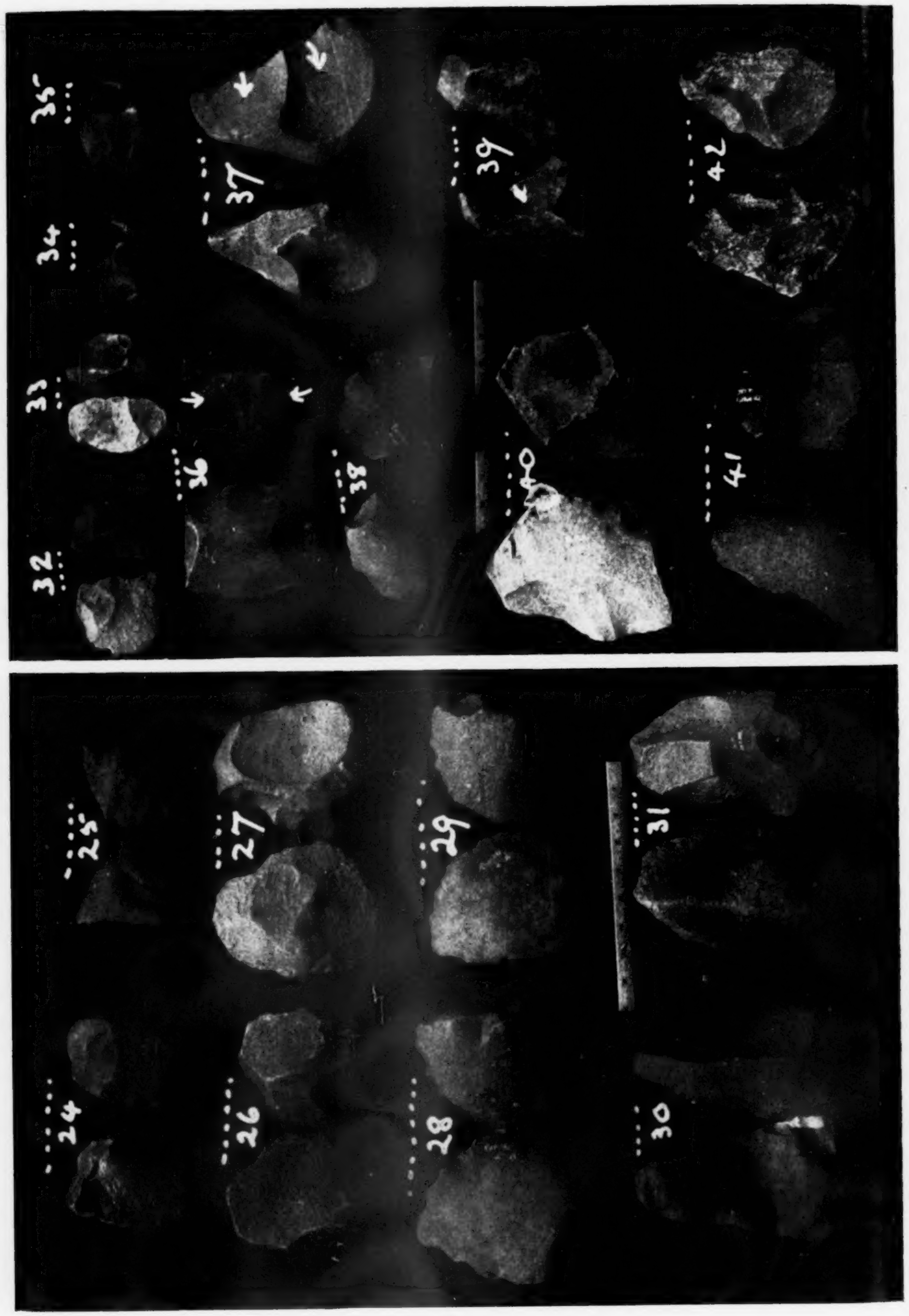

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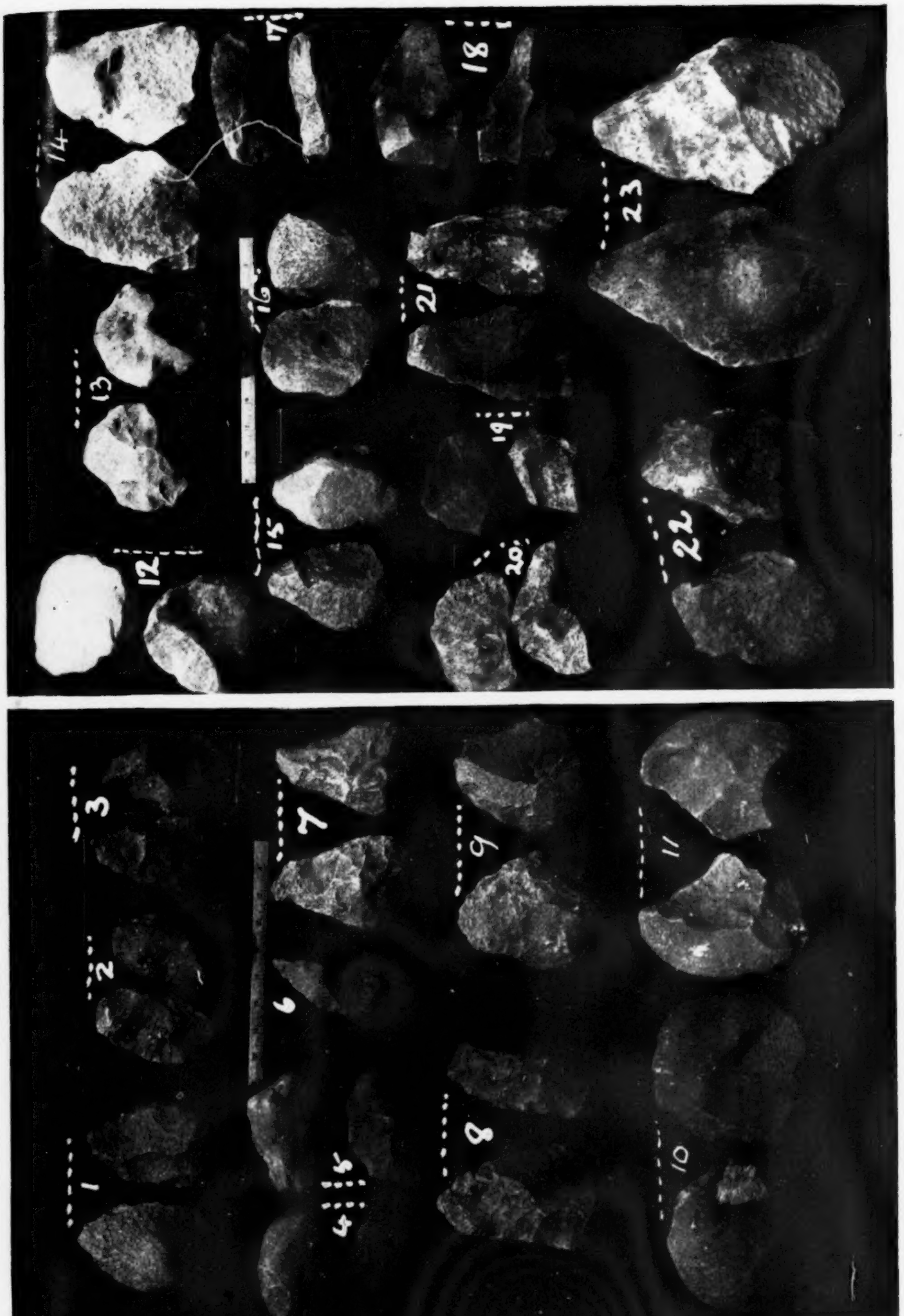

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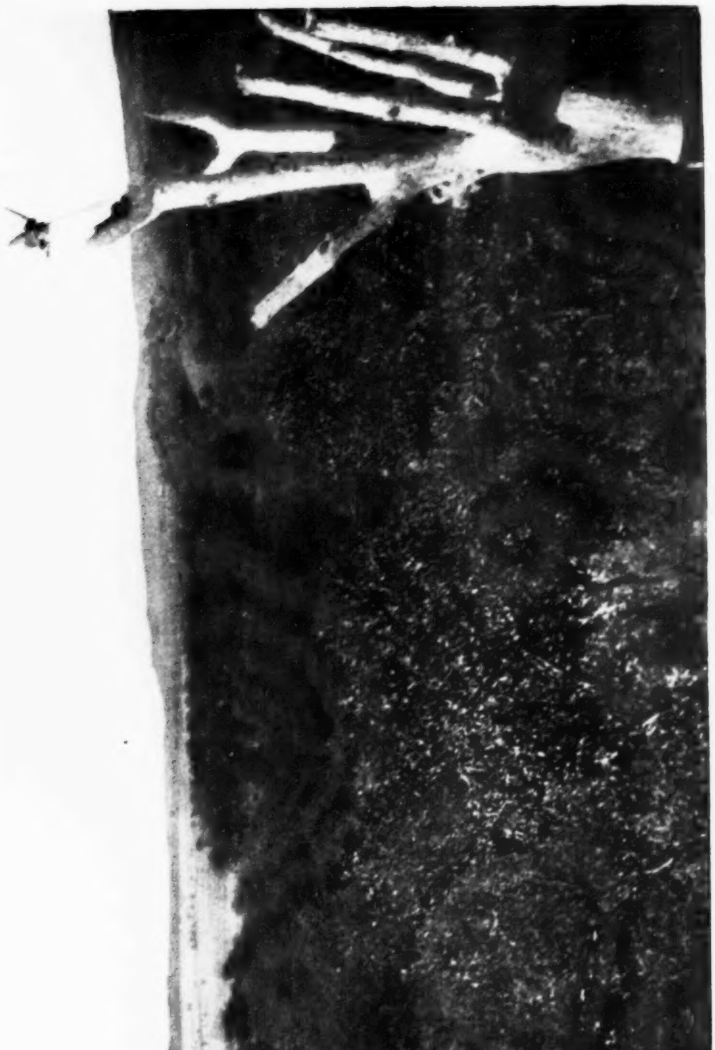

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A UNIVERSAL TEMPERATURE SCALE.

By Edgar Newbery.

(*A paper from the University of Cape Town*)

WITH SOME REMARKS ON AN ALTERNATIVE TEMPERATURE SCALE.

By R. Guelke.

(Read March 15, 1944.)

All the temperature scales at present in use are based upon the properties of a specific substance, water, and it is therefore impossible to express the dimensions of temperature in terms of the fundamental mass-length-time units.

Even when the so-called "Absolute Thermodynamic Scale" is employed, although the zero of the scale is based upon fundamental ideas of energy only, the magnitude of the degrees subsequently used are entirely dependent upon the interval between the boiling- and freezing-points of an arbitrarily chosen substance, water, under specific conditions (N.Atm.P.), also chosen in an arbitrary manner. This scale has therefore no real right to the title of "Absolute." Also chemically pure water itself is not a perfect reference substance, since the proportion of deuterium oxide varies slightly in different samples. For this, and other reasons, the U.S. Bureau of Standards has proposed that the calorie should be defined in terms of the Joule, and not as the heat capacity of 1 gram of water.

In general, two bodies are at the same temperature if no heat passes in either direction when the bodies are placed in contact with each other, and this can only occur if the "average kinetic energies of the molecules" of the two bodies are identical.

The expression "Kinetic energies of the molecules" throughout this paper is intended to refer only to the *external* translational energies of the molecules, and definitely excludes *internal* rotational, vibrational, and excitational energies which form a considerable proportion of the *total* molecular energies of polyatomic molecules.

It should therefore be possible to devise a temperature scale based upon molecular kinetic energies, which will be independent of the specific properties of any material substance, and therefore truly Universal.

The obvious zero of this scale will be the temperature at which the

molecules are at rest and therefore have no kinetic energy. This is the so-called Absolute Zero, or $-273{\cdot}15°$ C.

Now in the case of a gram molecule of a perfect gas,

$$PV = \frac{Nmc^2}{3} = RT,$$

where N, the Avogadro constant, has the value $6{\cdot}025 \times 10^{23}$. At a temperature of 0° C. = 273·15° A., the kinetic energy of a single molecule will be

$$\frac{1}{2}mc^2 = \frac{3}{2}\frac{PV}{N} = \frac{3 \times 1{\cdot}013 \times 10^6 \times 22414}{2 \times 6{\cdot}025 \times 10^{23}} \text{ ergs.}$$

Hence a change of temperature of 1° on the Centigrade or Absolute scale involves a change of kinetic energy of 1/273·15 of this, or $2{\cdot}070 \times 10^{-16}$ ergs per molecule.

For a Universal Scale of Temperature, we may define our fundamental unit as an increment of 10^{-16} erg of translational energy per molecule, and this will be quite independent of the nature of the molecule chosen so long as translational *kinetic* energy alone is considered.

Hence 1° A. = 2·070° U., and at any temperature of T° U. the kinetic energy of the molecule of any substance will be $T \times 10^{-16}$ ergs. A temperature of 0° C. will correspond with one of $273{\cdot}15 \times 2{\cdot}070 = 565{\cdot}4°$ U.

The dimensions of temperature measured on the U. scale will be the same as that of energy, *i.e.* ML^2/T^2.

Heat Capacity.—The obvious unit of heat capacity when using this scale will be the joule and not the gram-calorie. A substance having unit specific heat would be one in which 1 joule would raise the temperature of 1 gram by 1° U.

Since 1 calorie in Centigrade units = 4·185 Absolute joules, this would correspond with a specific heat of 2·070/4·185 = 0·4946 cals. per gram. This is almost exactly the specific heat of the paraffin $C_{16}H_{34}$ or hexadecane, though all the paraffins from C_{12} to C_{17} have very nearly the same value. These have boiling-points from 220° to 300° C., and since they are so closely related chemically, they behave as ideal liquid mixtures. Hence any of these, or any mixture of them, could be used for rough calorimetry. Specific heats measured in Universal units would be approximately double those measured in Centigrade units.

The only substance in which the sole effect of added heat is an increase of kinetic energy of the molecules is a monatomic gas. Since 1 gm. mol. of such a gas contains $6{\cdot}025 \times 10^{23}$ molecules, the energy required to raise the temperature 1° U. will be

$$6{\cdot}025 \times 10^{23} \times 10^{-16} \text{ ergs or } 6{\cdot}025 \text{ joules.}$$

The work done by the same gas if heated 1° U. at constant pressure is $1{\cdot}013 \times 10^6 \times 22414/565{\cdot}4 \times 10^7 = 4{\cdot}016$ joules.

Hence for a monatomic gas, in Universal units,

$$C_p = 10{\cdot}041, \qquad C_v = 6{\cdot}025, \qquad \text{and } R = 4{\cdot}016 \text{ joules/degree U.}$$

The accuracy of the proposed scale is dependent upon the accepted value of the Avogadro number, and this may be in error to the extent of 1 part in 1000.* It is therefore doubtful whether this or any similar scale will have any practical value. Nevertheless, the main object of this paper is to demonstrate that it is possible to devise a temperature scale based upon fundamental units of mass, length, and time, and independent of the properties of any material reference body.

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Ever since the introduction of the kinetic theory of gases, temperature has been identified as a measure of the mean kinetic energy of molecules in a particular state. It is, therefore, only logical to express this energy in terms of the c.g.s. unit. In some cases, however, it may be more convenient to express it in terms of easily observable quantities which may not be actual measures of energy. The best practical scale will in general be the one that can be reproduced with the greatest accuracy. As mentioned by Prof. Newbery, a temperature scale in terms of the mean kinetic energy of an individual molecule may be in error to the extent of one part in 1000 owing to the uncertainty of the Avogadro number. One measure of energy which is very convenient in spectroscopic and electrical measurements is the kinetic energy imparted to an electron when it "falls" through a field of 1 volt. This measure, known as the "Electron Volt," can be easily converted to energy, using the following relations:—

$$\tfrac{1}{2}m_e c^2 = qE,$$

where c = speed of electron,
q = charge on electron,
E = potential difference through which electron falls,
m_e = mass of electron.

Using the relation given by Prof. Newbery:

$$qE = \frac{\frac{3}{2}PV}{N}, \qquad \therefore \quad E = \frac{\frac{3}{2}PV}{Nq}.$$

* The value for the Avogadro number here used ($6{\cdot}025 \times 10^{23}$) is based upon measurements made by Mond and Bollman in 1936 using calcite crystals with X-rays of known wave-length, and is probably the most accurate figure available. The claim of an accuracy of only 1 in 1000 is perhaps an under-estimate of the value of this work.

The Avogadro number can be expressed by the Faraday number divided by the charge on the electron.

I.e. (using absolute electromagnetic units)

$$N = \frac{9649\cdot4}{q},$$

$$E = \frac{\frac{3}{2} \times 1\cdot01325 \times 10^{6} \times 22414 \times 10^{-8}}{9649\cdot4}. \quad \text{(E in volts.)}$$

$\therefore$ 0° C. or 273·15° A. will correspond to ·035304 Electron-volts, or 1° A. = 0·12925 electron-millivolts.

This measure of temperature (the electron millivolt) may have sufficient advantages to warrant its practical introduction. It can be converted into energy simply by multiplying by the charge on the electron. Most important, it is a quantity which can be very easily measured electrically. Convenient standards of voltage exist which are accurate to five figures.

The conception of the kinetic energy acquired by an electron accelerated in an electric field is very easily understood. This measure of temperature would also simplify the formulae relating to electronic emission.

If the relationship is used:

$$qE = h\nu, \qquad h = \text{Planck's constant}, \qquad \nu = \text{frequency},$$

the electron-millivolt, which is approximately 8° C., can also be very easily related to the emission or absorption of radiation.

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THE PETROLOGY OF THE MOUNT ARTHUR DOLERITE COMPLEX, EAST GRIQUALAND.

By Arie Poldervaart, M.Sc., Ph.D., University of Cape Town.

(Communicated by Frederick Walker.)

(With Plate IX and ten Text-figures.)

(Read May 17, 1944.)

Abstract.

A plug-like mass of Karroo dolerite, situate in the Mount Currie district of East Griqualand, is described in detail. By collapse of the roof, large blocks of sediments, belonging to the Stormberg series, were immersed in the magma. Three phases of igneous activity contributed to the formation of the complex. The first magma was tholeiitic, rich in iron oxides, and intruded along an outer ring-dike. Cauldron subsidence within the ring-dike led to the intrusion of a large volume of olivine-dolerite magma. The final phase consisted of a magma which was relatively poor in olivine. It is represented by a few narrow dikes and thin sheets. Interaction of the olivine-dolerite magma with the enveloped sediments produced tholeiites, in which pigeonite occurs instead of olivine.

CONTENTS.

I. Introduction.

A full account of the complex was first given by du Toit (1929, pp. 23–24). A map of the intrusion, likewise by du Toit, is included in the Survey map, Cape Sheet No. 35 (Matatiele). Elsewhere du Toit again referred to the complex and discussed its mode of intrusion in some detail (1920, pp. 11–12). The present author visited the area in 1941, when he spent three months collecting the necessary data for a more detailed petrological study. The extreme ruggedness of the country does not allow accurate mapping by a single individual, but from compass bearings and photographs a map was constructed whose accuracy was judged sufficient for the present purpose.

II. Acknowledgments.

The writer wishes to express his gratitude to Professor F. Walker, of the Cape Town University, and to Dr. A. L. du Toit for their interest and constructive criticism of this research. He is further indebted to Mr. J. A. Purchase, of Ashton, for his great hospitality and help in the field. The cost of the chemical analyses was met by a liberal grant from the National Research Council, which is here gratefully acknowledged. Professor F. Walker kindly allowed the writer to use two of his unpublished analyses of Mount Arthur rocks, for which due acknowledgment is here made.

III. Field Characters.

The location of the complex, and its relations to other Karroo dolerite intrusions, can be read from the Survey map. The intrusion is roughly pear-shaped in plan, and in size about seven miles long by four miles across. Apart from some side-intrusions, emanating from the complex itself, the dolerite mass stands alone. The dolerite forms a high plateau just over 7400 feet above sea-level, and rising 1500 feet above the surrounding plains.

The plateau is deeply cut by the drainage systems of the Krom and Umzimvubu rivers. Both rivers show youthful aspects within the complex, cutting deep, V-shaped ravines with many waterfalls and rapids, but develop intricate meanders as they enter the plains. Possibly the high plateau of Mount Arthur constitutes a remnant of the late Cretaceous (?) peneplane recognised by Dixey (1942, pp. 160–163).

The plateau is best developed in the south on the farm Falloden, but is deeply dissected in the north. Here also stand a number of conical peaks, of which Eagle's Nest (7580), Ben Nevis (7600), and Mount Arthur (7440) are the most prominent. In the west the Umzimvubu has cut a deep valley which here separates the complex from the Drakensberg. In the north the land falls steeply down to the ravine of the Indowana River, which marks

the boundary between Natal and the Cape Province. In the south-west the high ground is connected with a broad spur of Molteno sandstone, on which stands the Glendonald beacon (7491).

Except on the western side, the intrusion transgresses everywhere outwards at high angles, varying between 50° and 80°. Side-intrusions emerge from the central mass in the north-east and south-west. They take the form of sheets which transgress outwards at varying angles. The western margin of the complex is rather variable. An inward dip of about 30° is here also recorded. A long spur of Molteno sandstone has become detached from the Drakensberg and, undermined by a dolerite sheet, now dips towards the south-east at 5°.

The base of the intrusion is nowhere exposed. In shape it therefore resembles a plug or stock. Large blocks of Molteno beds, Red beds, and Cave sandstone are enveloped in the igneous rock. The inclusions dip in all directions, and are not in their normal position when referred to the strata surrounding the intrusion. Subsidences of over 1000 feet are frequently encountered. The margins of the inclusions are strongly metamorphosed, and in places fused to a glass. Cases of rheomorphic veining of dolerite by mobilised sediment were also observed. Inclusions of Stormberg lavas were not encountered.

The complex is traversed by three narrow dikes, which belong to the Transkeian dike-swarm of west-north-westerly trend. The surrounding sediments dip at 2°–5° in the same direction. The sediments partake in the general thinning of the Karroo system towards the north-east. Thus the Molteno beds are locally only about 1000 feet thick, while the Red beds and Cave sandstone measure respectively 400 feet and 200 feet. At the same time the base of the Molteno beds rises rapidly in the area, and forms the crest of the Drakensberg at the beacon watershed (8184). A further feature of interest is the volcanic neck of Thule, which lies just 2½ miles to the north-west of the complex. du Toit notes that this volcano "came into action unusually early, and that it was able to keep its chimney open while the Cave sandstone was being deposited over the area" (1929, p. 22).

IV. Petrography.

A. *Methods.*

All refractive indices for this study were determined by immersion methods, using sodium light. Axial angles and extinction angles were measured on a 4-ring universal stage. Modal compositions were determined with a Leitz integrating stage.

The compositions of the plagioclases were assessed from the average value for β; those of the olivines and orthopyroxenes from 2V and γ. For

the latter two mineral series the diagrams of Deer and Wager (1939, p. 21), Henry (1935, p. 223), and Hess and Phillips (1940, p. 280) were used. The compositions of the clinopyroxenes were obtained by a new method. By plotting the available analyses, a curve for the course of crystallisation of clinopyroxenes was drawn. Employing the diagram of Deer and Wager (1938, p. 20) for the values of γ, the compositions were found by the intersections with the course of crystallisation. In a few cases the compositions were confirmed by chemical analysis. The author hopes to discuss the pyroxenes in greater detail in the near future.

The appended map shows the approximate distribution of the various rock types, as constructed from a collection of over two hundred thin sections. The boundary lines are drawn arbitrarily and are not intended to represent sharply defined contacts. In the field gradual transitions between the types recognised here are generally encountered.

B. *Marginal Tholeiites.*

The type rock consists essentially of plagioclase (An_{54}), pyroxene ($2V: 44°$, $\gamma: 1{\cdot}730$, comp. $Wo_{31}En_{34}Fs_{35}$), and a dark mesostasis. The plagioclase laths are moderately zoned. Like pyroxene, crystals frequently contain irregular inclusions of mesostasis. Pyroxene is hypidiomorphic, prismatic in habit; pale brown in colour. Twinning on (110) is common and zoning is negligible. The fine-grained mesostasis shows margarites of brown pyroxene, skeletal feldspar, and jagged rods of iron ore. The latter also occurs as larger masses, moulded on pyroxene. Oval areas of opaline silica, surrounded by narrow rims of a dark-brown chlorite occur in the mesostasis. Another accessory is chlorophaeite, which shows the shape and characteristic cracks of fayalitic olivine. On Linton the rocks show flow structures, produced by parallellism of elonagted, platy crystals of plagioclase and pyroxene. Here too a pegmatitic representative of the tholeiite magma was found, containing broad plagioclase crystals (An_{46}) and large prisms of pyroxene ($2V: 43°$, $\gamma: 1{\cdot}738$, comp. $Wo_{26}En_{30}Fs_{44}$). The mesostasis is yellow-brown in colour and resembles a devitrified glass. Iron ore and oval patches of chalcedony are accessories. Chlorophaeite is absent.

No chilled phases of the tholeiite magma were found. Near sedimentary contacts there is only a slight decrease in grain-size, accompanied by an increase in the amount of interstitial material.

The contact with olivine-dolerite is likewise unchilled. The contact-tholeiites show evidence of interaction with the later olivine-dolerite magma. On Ashton the contact rock (53) is characterised by the pyroxene, 40 per cent. of which consists of pigeonite. The mineral occurs as large prismatic

crystals, showing salite structures and twinning on (010). Prismatic cleavages are feebly developed, but instead irregular cracks occur, similar

FIG. 1.—Marginal tholeiite. The rock consists mainly of plagioclase, ferroaugite, and a dense, black mesostasis. Chlorophaeite, probably replacing olivine, occurs as an accessory.

FIG. 2.—Pegmatitic phase of the marginal tholeiites. The mesostasis resembles a devitrified glass. Chlorophaeite is absent. Amygdules filled with chalcedony and surrounded by rims of brown chlorite occur scattered through the rock.

to those developed in olivine crystals. The axial angle varies from 0°–7°; the axial plane is in some crystals parallel, but in most perpendicular to (010). The composition is $Wo_{12}En_{53}Fs_{35}$ (γ: 1·715). The associated augite

is zonal (2V: 50°–46°, γ: 1·730–1·734), subophitic and pale brown in colour. Its composition is about $Wo_{33}En_{31}Fs_{36}$. By the appearance of serpentinised olivine, the pigeonite-tholeiites gradually merge into the adjoining olivine-

FIG. 3.—Pigeonitic transition phase of the marginal tholeiites. Note the columnar habit and rounded fractures of the magnesian pigeonite.

dolerites. Similar pigeonitic rocks (162, 163) occur along the north-western portion of the complex and may well represent other modifications of the tholeiite magma. Along the southern boundary the tholeiites in contact with olivine-dolerite fail to show pigeonite. The pyroxene is zonal and more magnesian (2V: 46°–40°, γ: 1·721–1·736), while the interstitial material is a micropegmatite on a sub-microscopic scale. Plagioclase, however, maintains its average composition at An_{54}.

C. *Olivine-Dolerites.*

General Statement.—The olivine-dolerites of Mount Arthur are chemically and mineralogically identical to those described at Elephant's Head and New Amalfi (Poldervaart, 1943, pp. 90–91). Modifications of the normal olivine-dolerites occur near the sedimentary inclusions.

The normal rocks consist of varying amounts of plagioclase, pyroxene, and olivine, with or without some interstitial micropegmatite and quartz. Iron ore, reddish-brown biotite, and apatite form the accessories. In the more acid rocks biotite is often replaced by chlorite, serpentine, or brownish-green hornblende.

The proportion of olivine varies from 18 per cent. to 1 per cent. by volume, while its composition ranges from Fa_{26} to Fa_{50}. Except for one rock (32),

occurring on the southern boundary, crystals are non-zonal, although different grains frequently have different compositions. The olivine of specimen 32 is strongly zoned, one crystal having the composition Fa_{32} in the centre and Fa_{52} at the margin. The grains show evidence of strain, and often a large crystal is surrounded by a host of small granules with approximately the same orientation.

Plagioclase generally constitutes more than half of the rock, while its composition ranges from An_{72} to An_{58}. Its habit and grain-size vary along the same lines as recorded at Elephant's Head (*ibid.*, p. 91).

The pyroxene includes augite, orthopyroxene, and/or pigeonite. Augite is very pale greenish-brown in the most basic rocks, pale brown in those poorer in olivine. Crystals are ophitic or subophitic and generally zonal. All values of 2V between 51° and 36° were recorded, while γ varies from 1·708 to 1·723. The composition varies accordingly from $Wo_{42}En_{41}Fs_{17}$ to $Wo_{32}En_{39}Fs_{29}$. Orthopyroxene occurs as subophitic or ophitic plates. Its composition varies between Of_{17} and Of_{41}. The more magnesian orthopyroxenes are of earlier formation than augite, while the ferriferous orthopyroxenes crystallised after augite. Often two generations occur in the same rock. Crystals invariably show the graphic intergrowth, thought to be due to exsolution of CaO. This occurs marginally in the orthopyroxenes of composition Of_{17}, but occupies the entire areas of more ferriferous crystals.

The most basic rocks contain orthopyroxene but no pigeonite. Rocks which carry but small amounts of olivine contain pigeonite and no orthopyroxene. Intermediate members show both pigeonite and orthopyroxene. The mutual relationship is often very difficult to ascertain, due to the fact that the pigeonites show a considerable range in composition; from $Wo_{10}En_{62}Fs_{28}$ to $Wo_{10}En_{40}Fs_{50}$. The more magnesian pigeonites crystallised prior to augite and orthopyroxene, while the ferriferous pigeonites are of late formation. The associations observed in the different sections are illustrated in fig. 4.

Zoning in pigeonites is strongest at the magnesian and ferriferous ends of the series, feeble in the intermediate members. The following measurements illustrate the zonal phenomena:—

A. Magnesian, colourless pigeonite. Core 2V : 12° (optic plane $\perp$ (010)), towards margin 2V: 0°, margin 2V: 8° (optic plane $\parallel$ (010)). Average value for γ: 1·706. Range in composition: $Wo_9En_{61}Fs_{30}$–$Wo_{16}En_{54}Fs_{30}$.

B. Ferriferous, brown pigeonite. Core 2V: 0°, margin 2V: 19° (optic plane $\perp$ (010)). Average value for γ: 1·736. Compositional range: $Wo_{10}En_{40}Fs_{50}$–$Wo_4En_{40}Fs_{56}$.

The so-called "pure" olivine-dolerites generally occur far removed from

sedimentary xenoliths. In closer proximity to such inclusions the rocks are considerably modified. Olivine is invariably altered to green or brown,

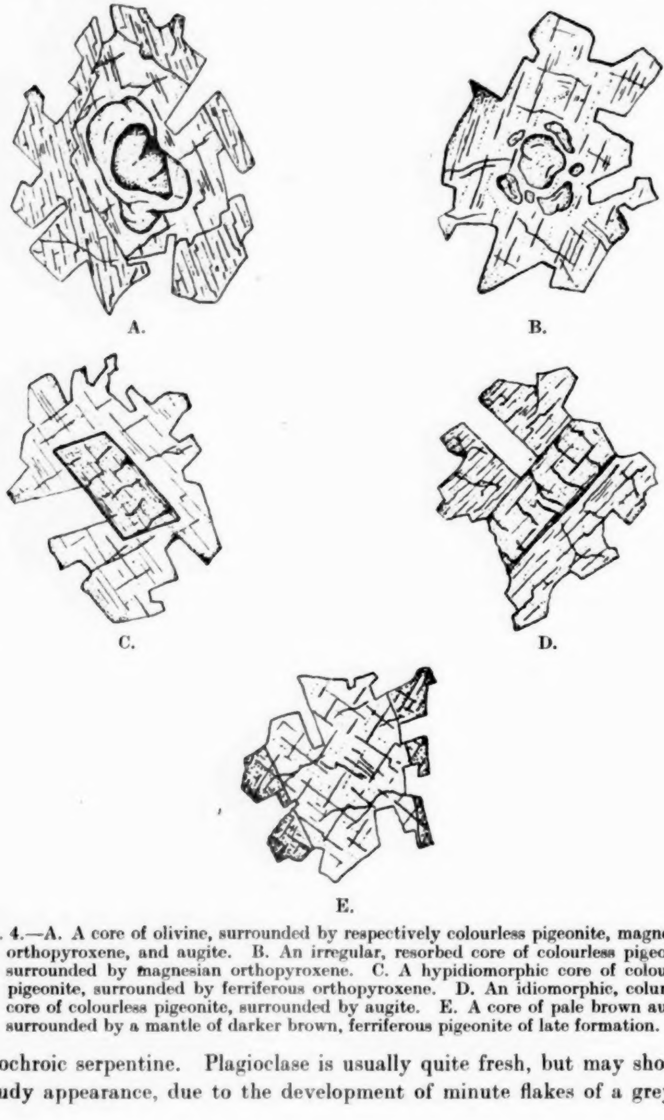

Fig. 4.—A. A core of olivine, surrounded by respectively colourless pigeonite, magnesian orthopyroxene, and augite. B. An irregular, resorbed core of colourless pigeonite, surrounded by magnesian orthopyroxene. C. A hypidiomorphic core of colourless pigeonite, surrounded by ferriferous orthopyroxene. D. An idiomorphic, columnar core of colourless pigeonite, surrounded by augite. E. A core of pale brown augite, surrounded by a mantle of darker brown, ferriferous pigeonite of late formation.

pleochroic serpentine. Plagioclase is usually quite fresh, but may show a cloudy appearance, due to the development of minute flakes of a greyish

white micaceous mineral. The pyroxene consists of augite and pigeonite, while othopyroxene is absent. Alteration to iron ore, chlorite, or green

FIG. 5.—Normal olivine-dolerite of the Kokstad type. More than 50 per cent. of the rock consists of plagioclase. Olivine occurs as large crystals. Augite and bronzite form ophitic plates.

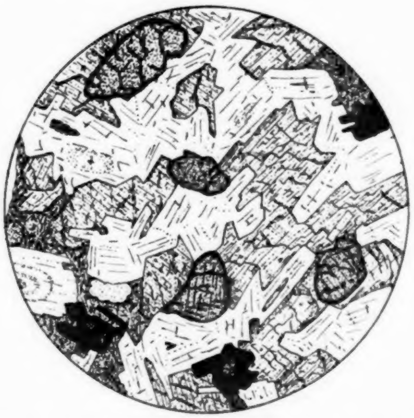

FIG. 6.—Modified olivine-dolerite. There is less plagioclase. Olivine is pseudomorphosed in brown, pleochroic serpentine. Pigeonite occurs instead of bronzite. A dense mesostasis replaces the micropegmatite of the normal rock.

fibrous actinolite is common. The interstitial material is a fine, brownish-grey mesostasis, usually intensely altered. Rounded grains of quartz with regularly arranged inclusions are often associated with the mesostasis.

Large rounded masses of chlorite, green serpentine, actinolite or calcite are also frequently encountered. It is to be noted that similarly modified rocks were recorded from the margins of the New Amalfi Sheet (*ibid.*, p. 93).

One peculiar, olivine-rich rock from Linton calls for further comment. It forms a small offshoot in rather coarse-grained Burghersdorp sandstone. All the olivine is altered. Grains which are embedded in pyroxene are pseudomorphosed in bluish-green bowlingite, while grains, formerly embedded in plagioclase, are now totally destroyed. The areas now closely resemble a fine-grained interstitial mesostasis and were listed as such in the mode (184). Pyroxene consists of augite only, but the zoning is abnormal. The following table shows the measurements made:—

TABLE I.

	Core.	Near Margin.	Margin.
Crystal A . .	30°	40°	51°
Crystal B . .	32°	41°	51°
Crystal C . .	38°	43°	51°
Crystal D . .	37°	42°	50°

γ varies from 1·704 to 1·713; the cores having the smallest values. The range in composition is therefore $Wo_{30}En_{50}Fs_{20}$–$Wo_{41}En_{39}Fs_{20}$.

The chilled phases of the olivine-dolerite magma are fine-grained basalts, occasionally showing variolitic textures. The porphyritic contents of the rocks are olivine (Fa_{15}), a little augite (2V : 51°) and glomeroporphyritic plagioclase (An_{72}). The analysed variolitic basalt (177) differs from the normal chilled phases in that the olivine is all altered to bowlingite, while plagioclase only occurs in the groundmass.

D. *Tholeiites.*

In the immediate vicinity of sedimentary inclusions the olivine-dolerites give way to tholeiitic rocks of rather variable character and grain-size. Similar tholeiites also occur along the northern margin of the complex. In many cases a gradual transition between olivine-dolerite and tholeiite is observed. In others, however, it is not clear whether the tholeiites are derived from the olivine-dolerite magma or the earlier tholeiite magma.

The rocks are characterised by the absence of olivine and the high degree of alteration, giving rise to such minerals as quartz, chlorite, serpentine, and hornblende.

Plagioclase is of rather variable composition (An_{70-50}). Generally the

lowest exposed rocks are richest in CaO. Crystals show a rapid drop in An. content near the margins, where An_{30} is normally recorded. The plagioclase is invariably intensely altered, but the margins remain clear of the dusty-grey, flaky alteration products. The pyroxene consists of augite and pigeonite. Normally the augite varies in composition between $Wo_{39}En_{38}Fs_{23}$ and $Wo_{32}En_{35}Fs_{33}$. Some tholeiites, however, contain augite of unusually high axial angles (2V: 59°–42°), indicating compositions $Wo_{44}En_{35}Fs_{21}$–$Wo_{34}En_{32}Fs_{34}$. Pigeonite is colourless, columnar, and of early formation.

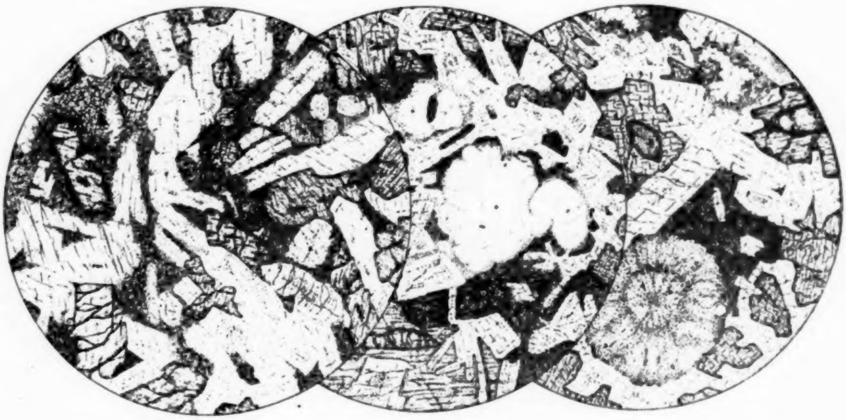

FIG. 7.—Tholeiitic types. The rocks contain less than 50 per cent. plagioclase. Olivine is rare and never occurs fresh. The pyroxene consists of ophitic or subophitic augite and columnar pigeonite. The interstitial material is a dense mesostasis. Grains of quartz, sometimes marginally converted to tridymite, may occur scattered through the rocks. Tholeiites in the immediate vicinity frequently show vesicles filled with chlorite, hornblende, or quartz.

The mineral is most abundant in the coarser-grained rocks. The interstitial mesostasis is normally fine-grained and brownish-grey in colour. At times the interstitial material may be micropegmatitic, but the intense alteration renders such patches a turbid greyish-white. Many tholeiites contain vesicles filled with chlorite, serpentine, actinolite or calcite. The vesicles are round or oval in section, and alteration is most pronounced in their vicinity. Analcite occurs in a few tholeiites in small quantities, filling interstices between feldspar laths. Quartz occurs in many sections, the grains showing undulose extinction. In the coarser grained tholeiites the quartz grains show resorbed, rounded outlines. In the fine-grained rocks, nearer the xenoliths, the quartz is insertal in habit. The grains often show aggregate polarisation and are surrounded by narrow rims of tridymite.

Hypersthene was only found in two tholeiites. In the one rock, adjacent

to Molteno sandstone, orthopyroxene (Of_{30}) occurs to the exclusion of pigeonite. The other rock, in contact with Cave sandstone, contains prisms of hypersthene (Of_{22}) and colourless, magnesian pigeonite. The orthopyroxene shows no trace of the graphic intergrowth.

An interesting exposure of a xenolith of Molteno sandstone occurs on the western slope of Mount Arthur peak. The sediment intermingles with the igneous rock, which is a chilled representative of the olivine-dolerite magma. Grains of quartz with wavy extinction occur scattered through

FIG. 8.—Mixed rock, consisting of the chilled phase of the olivine-dolerite magma and Molteno sandstone. The quartz xenocrysts are partially fused and surrounded by numerous columnar granules of a colourless pyroxene. The olivine phenocrysts are altered to a yellow, pleochroic serpentine.

the rock. The grains are surrounded by rims of pyroxene, which form small colourless prisms with oblique extinction. The quartz may be partly or wholly fused to a light brown glass, containing thin needles of a colourless mineral. The igneous part of the rock is basaltic, and shows phenocrysts of altered olivine, plagioclase, and a little augite. Olivine is altered to a yellow, weakly pleochroic serpentine. In the immediate vicinity of the xenolith the rock is essentially a fine-grained tholeiite without any trace of olivine. The quartz grains have entirely disappeared, but instead patches of a brown glass occur in the rock. In some instances the cores of these patches have further crystallised and resemble mesostasis. There is a distinct concentration of iron ore granules and little columnar crystals of a colourless clinopyroxene near such areas. Farther away the rock is a normal, medium-grained tholeiite, showing colourless pigeonite in addition to augite, but no olivine.

E. *Later Dolerites.*

The later phases of igneous activity invariably belong to an olivine-poor dolerite magma. The rocks are basaltic or fine-grained dolerites, and are matched by the B.K. type of dolerite, first encountered in the Calvinia district (Walker and Poldervaart, 1941 *a*, pp. 127–148). The basalts contain phenocrysts of plagioclase (An_{70}), olivine (Fa_{15}), with or without a little augite (2V: 50°). The fine-grained dolerites are characterised by having less than 50 per cent. plagioclase.

F. *Sediments.*

The sediments of the area belong to the Upper Beaufort or Burghersdorp beds and to the Stormberg series, subdivided into Molteno beds, Red beds, and Cave sandstone. Excellent descriptions of these strata are given by du Toit (1939, pp. 264–270), while the present author has included analyses of Burghersdorp sandstone and Molteno grit in a previous paper (1943, p. 116).

The rocks consist generally of feldspathic sandstones of varying grain-size, alternating with blue, green, or red shales and mudstones. The cementing material of the Burghersdorp and Molteno beds is mainly siliceous; that of the Red beds and Cave sandstone ferruginous or calcareous. The metamorphic equivalents of the sediments show great variations, depending on the composition of the original sediment and the grade of metamorphism attained. The shales and mudstones were converted to dense, black hornstones which break with conchoidal fractures. The sandstones recrystallised to quartzites and now show a mosaic of interlocking quartz grains, with a few interstitial patches of micropegmatite. At the extreme margins of the xenoliths the sandstones have been partially fused to a yellow-brown glass in which feldspar laths and small flakes of tridymite can be recognised. The remaining quartz grains show crenulated outlines and intricate strain shadows in polarised light. The more impure sandstones are converted to hornfelses which may contain biotite, magnetite, hypersthene, or a little augite. Cordierite is rare, if not completely absent.

Within the complex it proved impossible to differentiate between the Red beds and the Cave sandstone. Xenoliths never show the characteristic red colour, as all hæmatite has recrystallised as magnetite. Only one xenolith contained sufficient magnetite to identify it as belonging to the Red beds.

G. *Volumetric Measurements.*

Table II. shows the micrometric data of the rocks described above. Settling of magnesian olivine appears to have taken place in the early

TABLE II.—MICROMETRIC DATA.

Olivine-Dolerites.

	181.	14.	7.	32.	21.	8.	63.	119.	25.	116.	Average.	184.	133.	35.	178.	31.	114.	48.	Average.
Plagioclase	46·3	51·5	54·9	54·7	59·6	51·9	51·8	52·2	51·2	52·0	52·6	41·3	44·2	43·6	45·8	46·6	48·9	44·6	45·0
Pyroxene	32·6	36·5	33·4	36·4	29·2	36·1	30·7	38·4	29·4	35·8	33·9	28·9	35·9	37·9	35·3	38·9	36·7	41·7	36·5
Olivine	18·1	9·3	6·8	6·3	4·0	3·6	2·2	1·8	1·5	1·0	5·5	16·1	5·5	5·2	4·8	3·6	2·1	1·8	5·6
Iron Ore	0·7	0·8	2·0	0·7	1·5	1·3	2·3	1·6	2·1	1·5	1·4	1·2	2·4	2·4	1·7	1·6	2·5	2·2	2·0
Micropegmatite	1·8	..	2·9	1·9	5·7	6·0	13·0	6·0	15·8	9·7	6·3	..	..	..	..	..	..	..	..
Mesostasis	..	..	..	..	..	..	..	..	..	..	..	12·5	12·0	10·9	12·4	9·3	8·5	8·8	10·7
Biotite or Chlorite	0·5	1·9	..	..	..	1·1	..	..	..	..	0·3	..	..	..	..	..	1·3	0·9	0·3

Tholeiites.

	173.	163.	162.	18.	174.	88.	37.	199.	150.	153.	127.	60.	120.	67.	68.	146.	110.	82.	Average.
Plagioclase	41·3	42·8	43·8	45·9	48·3	48·8	48·9	48·8	48·7	47·7	47·6	46·5	44·9	44·2	42·3	39·8	35·0	26·4	44·0
Pyroxene	29·9	29·7	29·5	30·7	29·9	32·7	38·7	33·9	37·4	35·3	37·6	35·1	32·2	32·5	33·4	34·9	20·1	21·3	31·9
Iron Ore	3·3	3·6	4·3	7·7	3·0	2·0	2·4	1·8	2·8	1·6	2·5	3·3	3·1	3·5	3·7	7·2	3·7	4·6	3·6
Mesostasis	25·5	23·9	22·3	14·5	18·7	15·1	9·0	14·8	10·8	15·0	12·3	13·9	16·6	17·8	20·6	18·1	41·2	46·1	19·8
Chlorite or Hornblende	..	..	0·1	1·2	0·1	1·4	1·0	0·7	0·3	0·4	..	1·2	3·2	2·0	..	..	..	1·6	0·7

Marginal Tholeiites.

	192.	24.	5.	194.	23.	198.	187.	53.	22.	Average.
Plagioclase	24·1	25·8	33·7	37·2	38·4	43·4	43·6	46·6	50·6	38·1
Pyroxene	23·1	21·7	24·1	27·9	29·2	32·1	27·1	40·5	35·1	29·0
Iron Ore	9·8	8·0	6·3	4·6	6·1	2·8	1·5	0·9	2·0	4·7
Mesostasis	41·9	43·8	35·9	29·6	23·3	20·7	27·8	11·9	12·3	27·5
Quartz + Chlorophaeite	1·1	0·7	..	0·7	3·0	1·0	..	0·1	..	0·7

stages of crystallisation. The process is clearly illustrated by the three modes of olivine-dolerites from the south-eastern corner of the complex (14, 7, 8). The vertical interval between specimens 14 and 7 is 50 feet; that between specimens 7 and 8 100 feet. The so-called "pure" olivine-dolerites of Mount Arthur show a remarkably close resemblance to those developed at Elephant's Head and New Amalfi. There can be little doubt that the same magma was involved.

Olivine decreases rapidly in amount to about 5 per cent., whence its decrease is more gradual. No true picrites were observed at Mount Arthur, but the occurrence of specimen 181 indicates that such rocks may be expected at greater depths. A characteristic feature of the series is the sharp increase in plagioclase. The peak in the amount of plagioclase reaches 60 per cent., and drops abruptly to 52 per cent. on the more "acid" end. It may well be that settling of early formed plagioclase occurred to some extent. The mineral crystallised just after the bulk of the olivine, and thus became concentrated at higher levels than the orthosilicate. Similar plagioclase-rich layers occur at Insizwa just above the picrites (Scholtz, 1936, p. 105). The variation of pyroxene is highly irregular, due to its late period of crystallisation and its reaction relation with olivine.

Besides the "pure" olivine-dolerites, other olivine-bearing rocks were encountered, either marginally or near the sedimentary inclusions. Olivine is never fresh in these rocks, while plagioclase occurs in amounts which are always less than 50 per cent. Similar rocks occur marginally in the New Amalfi Sheet.

By the disappearance of olivine, the modified olivine-dolerites in turn grade into the somewhat variable tholeiites. In these rocks the amount of plagioclase again remains below 50 per cent. It is further noteworthy that the pyroxene of specimens 174–127 (containing about 48 per cent. plagioclase) has exceptionally high axial angles, reaching 59° in some individuals. The pyroxene of the other tholeiites is normal for the Karroo dolerites, 2V being generally below 50°.

The micrometric data of the marginal tholeiites likewise show great variation. They are very similar to the tholeiites found marginally in the Elephant's Head dike. The latter contain a little serpentinised olivine, absent in the Mount Arthur rocks. Pigeonitic varieties were apparently developed by interaction with the olivine-dolerite magma. This renders it impossible to distinguish pigeonite-tholeiites produced from the olivine-dolerite magma, from those developed from the marginal tholeiites. In some cases the origin of the tholeiites is established by the field relations, but in others no such clues are afforded.

TABLE III.

Chemical Analyses.

	177.	181.	14.	60.	67.	150.	174.	53.	163.	162.	194.	El.H. 70.	192.	Cave Sandst.
SiO_2	50·22	47·82	48·77	51·62	52·04	53·52	52·52	52·92	53·27	53·15	53·03	49·80	52·52	82·54
Al_2O_3	15·88	14·48	16·02	15·07	14·26	13·68	14·98	14·68	13·96	15·28	13·92	14·38	11·26	9·76
Fe_2O_3	2·12	1·43	0·89	2·20	2·77	1·76	2·58	1·72	3·85	2·27	2·21	3·67	2·88	0·31
FeO	8·38	9·44	9·27	8·37	9·27	9·85	7·62	8·17	8·74	8·82	10·24	11·03	14·22	0·52
MgO	8·47	14·52	11·71	6·84	6·12	6·26	6·13	7·32	4·93	5·38	4·62	4·52	2·57	0·27
CaO	9·58	8·48	9·13	10·57	9·04	9·97	11·56	11·05	8·22	9·46	9·36	8·82	7·22	0·14
Na_2O	1·32	1·42	1·54	1·94	3·13	2·11	1·84	2·02	2·37	2·38	2·55	2·23	1·65	2·12
K_2O	0·68	0·39	0·50	0·50	0·91	0·77	0·62	0·56	1·09	0·93	0·92	0·82	1·34	2·58
H_2O +	1·42	1·38	1·25	0·97	1·04	1·18	0·87	0·96	1·02	1·16	1·19	1·66	1·48	1·30
H_2O −	0·57	0·20	..	0·73	0·18	..	0·16	..	0·35	..	0·32	0·15	1·37	0·25
TiO_2	0·75	0·44	0·54	1·04	1·06	0·88	0·97	0·51	1·58	0·82	1·38	2·54	2·56	0·09
MnO	0·32	tr.	0·22	0·32	0·33	0·21	0·19	0·23	0·26	0·22	0·36	0·16	0·41	..
P_2O_5	0·05	0·07	tr.	tr.	tr.	tr.	0·08	tr.	0·09	tr.	0·08	0·29	0·23	tr.
CO_2	..	..	..	..	..	..	..	..	..	..	..	tr.	tr.*	..
Total	99·76	100·07	99·84	100·17	100·15	100·19	100·12	100·14	99·73	99·87	100·18	100·07	99·71	99·88

Norms.

	177.	181.	14.	60.	67.	150.	174.	53.	163.	162.	194.	El.H. 70.	192.	Cave Sandst.
Qu.	3·66	..	..	4·74	0·30	5·67	6·66	4·02	8·94	5·19	5·82	6·18	13·02	59·22
Or.	3·89	2·22	2·78	2·78	5·56	4·46	3·34	3·34	6·67	5·56	5·56	5·00	7·78	15·57
Ab.	11·00	12·05	13·10	16·24	26·72	17·82	15·72	16·77	20·44	20·44	21·48	18·34	14·15	17·82
An.	35·58	31·97	35·31	31·24	21·96	25·58	30·86	29·47	23·91	28·08	23·63	26·97	19·46	0·83
Di. { Wo.	4·76	3·94	4·18	8·93	9·63	9·78	10·79	10·67	6·61	7·89	9·28	6·26	6·50	Cor.
Di. { En.	2·80	2·60	2·60	5·00	5·00	4·90	6·10	6·00	3·40	3·90	4·00	2·90	1·70	3·16
Di. { Fs..	1·72	1·06	1·32	3·56	4·36	4·88	4·22	4·22	3·04	3·83	5·28	3·30	5·15	..
Hy. { En.	18·40	17·30	16·90	12·10	10·30	10·75	9·20	12·30	8·90	9·55	7·60	8·40	4·70	0·70
Hy. { Of..	11·35	7·26	9·11	8·71	9·11	10·69	6·34	8·98	7·66	9·50	9·90	10·16	14·92	0·53
Ol. { Fo.	..	11·48	6·86	..	..	..	..	..	..	..	..	..	..	..
Ol. { Fa.	..	5·51	4·08	..	..	..	..	..	..	..	..	..	..	..
Il.	1·37	0·76	1·06	1·98	2·13	1·67	1·98	0·91	3·04	1·52	2·74	4·71	5·02	0·15
Mt..	3·02	2·09	1·39	3·25	4·18	2·55	3·71	2·55	5·57	3·25	3·25	5·34	4·18	0·46
Ap..	0·17	0·34	..	..	..	..	0·34	..	0·34	..	0·34	0·67	0·34	..
$CaCO_3$	..	..	..	..	..	..	..	..	..	..	..	..	..	..
H_2O	1·99	1·58	1·25	·170	1·22	1·18	1·03	0·96	1·37	1·16	1·51	1·81	2·85	1·55
Total .	99·71	100·16	99·94	100·13	100·47	99·93	100·29	100·19	99·89	99·87	100·39	100·04	99·77	99·99

Modes.

	Variolitic Basalt.													Cave Sandstone.
Olivine		19·6	11·2	..	..	..	..	..	..	..	..	0·5	..	
Plagioclase		41·1	45·3	41·9	40·0	43·7	44·2	41·7	39·1	39·8	33·9	33·4	21·5	
Pyroxene		36·3	40·4	39·8	37·1	42·2	34·4	45·6	34·1	33·7	32·0	26·5	25·9	
Iron Ore		1·1	1·8	5·3	5·6	4·5	4·9	1·4	5·8	6·9	7·4	13·5	15·5	
Microp. and Quartz		1·5	..	..	..	..	..	..	..	..	..	..	..	
Mesostasis		..	..	12·0	15·5	9·3	16·4	10·3	21·0	19·5	26·0	20·5	36·0	
Biot. Hornbl. Serp.		0·4	1·3	1·0	1·8	0·3	0·1	..	..	0·1	..	5·6	..	
Chloroph. Chalced.		..	..	..	..	..	..	1·0	..	..	0·7	..	1·1	
$\frac{(FeO + Fe_2O_3).100}{MgO + FeO + Fe_2O_3}$	55·4	42·8	46·5	60·7	66·3	65·0	62·5	57·5	71·9	67·3	73·0	76·5	86·9	n.d.
Specific Gravity	2·98	3·07	3·04	2·90	2·89	3·00	2·92	2·98	2·91	2·90	3·04	3·00	3·13	2·68

177. Variolitic basalt, Linton, Umzimvubu valley, next to road.
181. Olivine-rich dolerite, Linton, Umzimvubu valley, 50 feet N. of 177.
14. Olivine-dolerite, Ashton, bottom of waterfall, S.W. of house.
60. Tholeiite, N. end of large Cave sandstone xenolith, centre of Falloden.
67. Tholeiite, between two large Molteno sandstone xenoliths, S.W. of Falloden.
150. Tholeiite, top of eastern boundary, N. of poort cut by Krom River, Glencoe.
174. Tholeiite, 100 yards N. of Cave-Molteno xenolith on boundary Falloden–Ben Nevis–Wansbeck.
53. Pigeonite-tholeiite, in valley cut by third river N. of Ashton house,
163. Pigeonite-tholeiite, along western boundary, Watershed.
162. Pigeonite-tholeiite, southern end of exposure, Watershed.
194. Marginal tholeiite, E. along Umzimvubu valley, Linton.
El. H. 70. Tholeiite, top of Elephant's Head peak.
192. Pegmatitic phase of marginal tholeiites, Umzimvubu valley, Linton.
Cave Sa. Top of Drakensberg, along road from Afzondering into Basutoland, Zureka.

V. Chemistry.

Twelve specimens of dolerites and tholeiites, and one of Cave sandstone, were chemically analysed by Mr. F. Herdman. The analyses, together with their norms and modes, are shown in Table III.

A. *The Olivine-Dolerite Magma.*

The olivine-dolerite magma, which succeeded the tholeiite magma in the formation of the Mount Arthur complex, represents a distinct phase in the intrusive history of the Karroo. The available evidence indicates that this phase is particularly well developed in the Transkei, giving rise to a new type of Karroo dolerite, named here the Kokstad type. The Kokstad type of dolerite closely resembles the Agterkop type, recognised in the Calvinia district (Walker and Poldervaart, 1941 *a*, p. 137), although the latter is richer in iron oxides. In view of the abundance of such dolerites in the Kokstad district it is here proposed to drop the term "Agterkop type" and to adopt instead the name Kokstad type for all dolerites of similar character.

Dolerites of this type are coarse-grained, subophitic, olivine-bearing rocks in which the percentage of plagioclase (by volume) is greater than 50 per cent. Olivine occurs in varying amounts, but is generally a magnesian variety. The bulk of the pyroxene is augite (2V: 50°–40°). Orthopyroxene occurs in the dolerites with more than 4 per cent. olivine. With less olivine its place is generally taken by pigeonite.

Olivine-dolerites of the Kokstad type are abundantly represented in the differentiated masses of Ingeli, Insizwa, Tonti, and Tabankulu, and the great sills of Flagstaff, Libode, Mount Prospect, and Butterworth. The Elephant's Head dike and the New Amalfi Sheet were occupied by the same magma. The great Fishback dike, which terminates in a thick sheet at Franklin (du Toit, 1929, p. 25), likewise consists of olivine-dolerite of this type.

Magmatic variation was studied in detail in the Insizwa lopolith (Scholtz, 1936, pp. 119–122) and the Elephant's Head and New Amalfi intrusions. The magma shows medium fractionation at Insizwa, but at New Amalfi strong magmatic fractionation is indicated. Fig. 9 illustrates the early and middle stages of crystallisation of the olivine-dolerite magma. It was found that a more comprehensive diagram was obtained by plotting the analyses against the ratio $\frac{FeO + Fe_2O_3}{MgO + FeO + Fe_2O_3}100$ than against SiO_2. Although only the analyses of Insizwa, Elephant's Head, New Amalfi, and Mount Arthur were plotted in the diagram, other analyses of Kokstad-type dolerites, as yet unpublished, were also taken into account.

The characteristics of the olivine-dolerite magma are well shown by the diagram. The early precipitation of magnesian olivine with a little chromi-

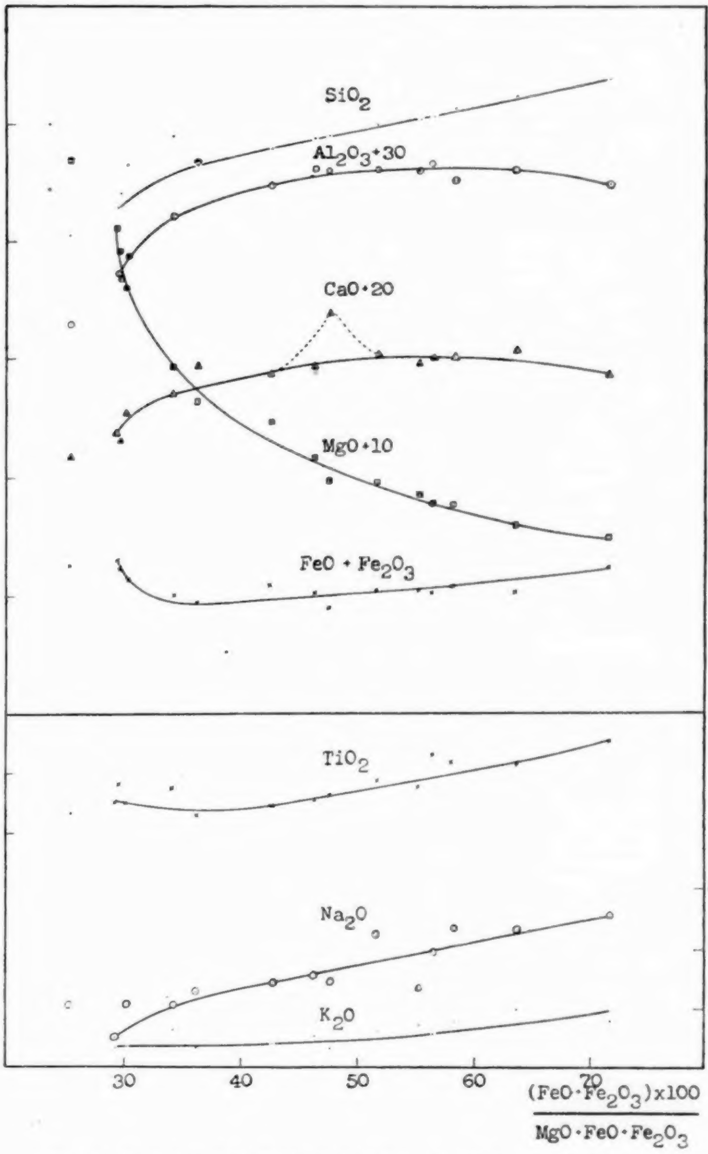

FIG. 9.—Variation of the Rocks derived from the Olivine-Dolerite Magma.

ferous magnetite is reflected in the sharp declines of the curves for MgO and FeO. Plagioclase was also of early crystallisation. The CaO curve has been smoothed, although this neglects the striking increase in the amounts of palgioclase exhibited by the micrometric data. The dotted line reflects these data better, and shows a sharp maximum in the curve. During the middle stages of crystallisation plagioclase and pyroxene separated simultaneously, becoming progressively enriched in soda and iron respectively. Thus the curves for CaO, MgO, and Al_2O_3 show a gradual decline, while there is an increase in the proportions of all other oxides. The increase in the proportions of FeO, Fe_2O_3, and TiO_2 is a characteristic feature of the olivine-dolerite magma. The closing stages of crystallisation have been discussed elsewhere (Poldervaart, 1943, pp. 98–100). They are of little importance in the present study, as interaction with included sediments was apparently most prominent during the middle stages of crystallisation. The normal trend of differentiation was thereby modified and different rocks were produced.

It is clearly of importance to gain some idea concerning the original composition of the magma. An analysis of the chilled phase was therefore made. The rock is a variolitic basalt which occurs adjacent to the olivine-rich dolerite 181, on Linton. As a reflection of the original magma the analysis (177) is not entirely satisfactory. Olivine occurs in smaller amounts than in the other chilled phases, and is invariably altered to bowlingite. Glomeroporphyritic plagioclase, so conspicuous in the basalts of other chilled contacts, is also absent in the analysed specimen. The lack of further analyses of chilled modifications unfortunately prevents a more accurate estimation of the composition of the original Kokstad magma.

B. *Marginal Tholeiites.*

The marginal tholeiites, representing the remnants of the earlier ring-dike of Mount Arthur, agree closely with the tholeiites of the Elephant's Head dike (Table III). Both are characterised by their low MgO and high percentages of iron and titanium oxides. The Elephant's Head tholeiite still retains a few altered crystals of olivine, but in the Mount Arthur rocks chlorophaeite occurs instead of olivine. As argued in the case of the Elephant's Head dike, the earlier tholeiite magma is thought to represent a small portion of the olivine-dolerite magma, which differentiated prior to injection. Differentiation was apparently effected by the precipitation of olivine, plagioclase, augite, and a little picotite in depth.

The pegmatitic phase of the tholeiite magma represents an extreme in composition. The analysis (192) is the most iron-rich recorded in the Karroo. It is clear that potash, iron, and titanium became concentrated in the "wet"

fractions of the magma. Consideration of the micrometric data further shows that these constituents accumulated in the glassy mesostasis. In a later paper on Karroo dolerites the problem of the formation of dolerite-pegmatites will be discussed in greater detail.

C. *Transition Phases of the Marginal Tholeiites.*

Bordering the exposures of the marginal tholeiites, transition rocks are found, which gradually pass into normal olivine-dolerites. The transition tholeiites show considerable variation in their chemical and mineralogical characters. It is believed that they are the result of the action of the olivine-dolerite magma upon the already solidified marginal tholeiites. The variations exhibited are attributed to:

a. The varying intensity and duration of the magmatic attack.

b. The variation of the magma itself during crystallisation.

c. Local variations in the magma due to the incorporation of resurgent gases from neighbouring xenoliths.

In Table IV the relevant analyses have been recalculated as water-free and to 100 per cent.

TABLE IV.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	Na_2O.	K_2O.	TiO_2.	MnO.	P_2O_5.	Total.
194 . .	53·7	14·1	2·2	10·4	4·7	9·5	2·6	0·9	1·4	0·4	0·1	100·0
163 . .	54·1	14·2	3·9	8·9	5·0	8·4	2·4	1·1	1·6	0·3	0·1	100·0
162 . .	53·9	15·5	2·3	8·9	5·5	9·6	2·4	0·9	0·8	0·2	..	100·0
53 . .	53·4	14·8	1·7	8·3	7·4	11·1	2·0	0·6	0·5	0·2	..	100·0
14 . .	49·5	16·2	0·9	9·4	11·9	9·3	1·6	0·5	0·5	0·2	..	100·0
El. H. 58 .	49·1	15·9	0·2	8·7	9·8	13·9	1·4	0·3	0·6	..	0·1	100·0

The high CaO of analysis 53—the pigeonite-rich transition tholeiite—appears to indicate that the magmatic action was most pronounced just after the crystallisation of the bulk of the olivine. To illustrate this, one of the Elephant's Head analyses was included in the table. The analysis is fairly representative of this period in the crystallisation-sequence. Specimens 162 and 163 are believed to have resulted from the action of a portion of the magma, locally modified by resurgent volatiles from nearby blocks of Stormberg sediments. The analyses show only minor differences from the composition of 194, and do not reflect the changes observed under the microscope. As a result of the magmatic attack upon the earlier igneous rock, pigeonite was formed, while the plagioclase became enriched in anorthite. Unfortunately the available data do not allow for a closer interpretation of the mechanism of the conversion.

D. *Tholeiites.*

Near the immersed blocks of Stormberg sediments the olivine-dolerites gradually change into tholeiites of varying character. Despite their considerable variation the following changes appear to be consistent in all the rocks. Olivine is first pseudomorphosed in pleochroic serpentine, and finally disappears altogether. Pigeonite forms a prominent part of the pyroxenes. Orthopyroxene is always absent. The interstitial micropegmatite is replaced by a mesostasis which gradually increases in amount as the included sediments are approached. The mesostasis is dark in colour and rich in iron ore and alkalies. Hydrous minerals, such as hornblende and serpentine, become more prominent, and finally occupy vesicles, together with quartz and calcite. Some tholeiites also contain irregular areas of quartz which are marginally crenulated and converted to tridymite.

It is clear that these changes must in some way be connected with the Stormberg xenoliths. It is also apparent that their immersion thoroughly changed the normal crystallisation course of the magma. On the other hand, the analyses (174, 60, 67, and 150) show that the observed changes could not have been effected by simple solution of, and magmatic reaction with, the included sediment. Examples of magmatic reaction encountered in the complex are also invariably on a microscopic scale. Neither is there any reason to assume that the tholeiites were produced by the metasomatic conversion of the sediment by the magma. It has been amply demonstrated that such a process would result in the formation of granophyres of quite typical appearance (Walker and Poldervaart, 1942, pp. 285–307, and Poldervaart, 1943, pp. 107–113). At Mount Arthur no trace of such metasomatic granophyres was found. The sediments were merely thermally metamorphosed and sometimes marginally fused to a glass.

The changes observed in the series olivine-dolerite–tholeiite indicate that the magma was enriched in volatiles near the xenoliths. It is here assumed that these volatiles were of the nature of resurgent gases, liberated by the gradual heating-up of the large blocks of Stormberg sediments. The resurgent gases were incorporated in the magma beyond the saturation point, as indicated by the partial vesiculation of some tholeiites. The process visualised must necessarily have been both slow and prolonged. Thus a gradual heating-up of the sediment resulted in a slow and prolonged release of resurgent gases. As magmatic diffusion of material is an even more retarded process than diffusion of temperature (Bowen, 1921, pp. 295–317), a magma-zone, rich in volatiles, was formed immediately around the xenoliths. The latter sank through this modified magma, thus—(*a*) reaching new levels which in turn were enriched in volatiles, and (*b*) causing currents

which promoted mixing with unmodified magma and a more even distribution of the volatile elements. The continued foundering of the sediments, and the outward migration of the resurgent gases effectively prevented the metasomatic conversion of the sediment by the magma.

Pronounced changes were effected in the modified portions of the magma. The presence of the volatile phase—mainly H_2O—prevented iron from combining with silica to form pyroxene. Thus late iron ore was precipitated in greater quantities than in the normal dolerites. The volatiles, which acted as fluxes, also facilitated the formation of an interstitial mesostasis. The total absence of orthopyroxene, and its substitution by pigeonite, confirms earlier suggestions that pigeonite becomes a stable phase in the presence of a sufficient concentration of volatiles (Walker, 1940, p. 1090, and Poldervaart, 1943, p. 96). All these changes may be observed within one section of the mixed rock found on the western slope of Mount Arthur peak.

The analyses again fail to reflect the great changes in the mineralogical make-up observed in the tholeiites. Partly this is due to the fact that the least "altered" rocks were selected for chemical analysis. Naturally these rocks do not represent extreme members of the series. On the other hand, the addition of resurgent volatiles resulted mainly in a change of the magmatic course of crystallisation, and had little effect on the bulk composition of the rocks crystallising from such a magma. The analyses show that there was some migration of alkalies within the volatile-rich zones, but all other constituents show little variation.

The petrological importance of the above process is obvious. Many hitherto puzzling relations may well be explained by the theory that olivine-dolerite is converted to tholeiite by a concentration of volatiles distilled from adjacent sediments. The New Amalfi Sheet contains marginally tholeiitic rocks, although the centre consists of differentiated olivine-dolerites. Above the granophyre band similar tholeiites occur, but olivine-dolerites are found below the granophyric zone. Apparently the down-stoping of the sediment resulted in the release of resurgent gases from the stoped sediment. The volatiles collected above the sediment and converted the dolerite there to tholeiite. After the release of the resurgent gases, magmatic emanations from below effected the metasomatic conversion of the sediment to granophyre. At Hangnest, in the Calvinia district, tholeiitic modifications of the bronzite-dolerite of the sill were found in a wedge above a stoped strip of sediment near the upper contact (Walker and Poldervaart, 1941 *b*, p. 435). It seems possible that distillation of volatiles from the stoped sediment facilitated the formation of tholeiitic types.

The author is not prepared to accept the above explanation for all observed cases of the conversion of dolerite to tholeiite. Nevertheless he

considers that the Mount Arthur complex demonstrates that a process of distillation of resurgent volatiles from sediment is capable of effecting this change on a comparatively large scale. More evidence is needed before this process, with its limitations, can be assessed in its true perspective.

VI. Mechanism of Intrusion.

A. *Sinking of Sediments in Basaltic Magma.*

Foundering of sediments, included in Karroo dolerite, has been recorded from three intrusions: at Mount Arthur, and in two intrusions near Birds River Siding (du Toit, 1911, pp. 132–134). In all three instances the sediments consist of the three uppermost, essentially arenaceous series of the Karroo system: Molteno beds, Red beds, and Cave sandstone. Specific gravity relations fail to explain these observations. Walker (1940, p. 1088) calculates the specific gravity of the Palisade magma at the time of emplacement as 2·64, assuming an intrusion temperature of 1100° C. Daly (1933, p. 277) gives the specific gravity range of sandstone, as solid blocks at 1100° C., as 2·09–2·61. These figures would indicate that sandstone xenoliths do not sink in normal basaltic magma. In a general survey of the Karroo, numerous thick sills were encountered, containing xenoliths of Beaufort or Ecca sandstone. Although more argillaceous, and therefore of higher specific gravity, such xenoliths show no evidence of foundering. Clearly some additional process must be invoked to explain the sinking of more arenaceous, lighter blocks of sediment in a magma which was slightly more basic than the average Karroo magma.

Significantly, only the three uppermost sedimentary beds of the Karroo system were subject to sinking on a large scale. It is thought that roof-foundering in Mount Arthur occurred a comparatively short time after the deposition of the Cave sandstone, and before the entire bulk of the Stormberg lavas was extruded. Evidently the sediments of the Stormberg series were not yet completely consolidated and contained appreciable amounts of connate waters. Upon immersion of the sediment in the magma the volatile elements became resurgent and were incorporated in the magma. Thus a zone of volatile-rich magma was formed immediately around the xenoliths. The chemical and mineralogical effects of the incorporation of such volatiles by a basaltic magma have been discussed above. Here it is of interest to note that the resurgent gases would have produced a decrease in the specific gravity of the modified magma. Evidently the specific gravity of the magma in the immediate vicinity fell below that of the sediment, resulting in the sinking of the latter. As the release of volatiles from the larger xenoliths was a prolonged process, foundering of these blocks became prolonged. Sinking of the xenoliths caused a more even

distribution of the volatiles, which eventually migrated upwards under the law of gravity. Thus tholeiites are found on all the highest points of the complex. du Toit * suggested that the sinking of the xenoliths was further promoted by the action of a downward force—a sucking-down of the xenoliths—effective during the subsidence of the central block. Such a force would have been even more effective if the specific gravity of the magma around the xenoliths were lowered by the incorporation of resurgent gases. The combined action of those two processes resulted in the xenoliths finally reaching depths of well over 1000 feet.

From a great many determinations the average specific gravity of the olivine-dolerites—determined with the Walker balance—was found to be 2·98. The specific gravity values of the tholeiites show variations between 2·77 and 2·94, while the average was found to be 2·87. The specific gravity of the Cave sandstone was determined as 2·68, that of the Molteno sandstone as 2·66 (average values). These results appear to support the above argument, particularly if it be remembered that the bulk of the volatiles must have escaped upon the solidification of the magma.

B. *Cauldron Subsidence of Mount Arthur.*

The volcanic effusions of the Stormberg series terminated a prolonged period of sedimentation. During this period a great thickness of practically horizontal deposits had accumulated in the Karroo geosyncline. As a result of the volcanic outbursts the region was elevated, and in places arched up in anticlinal fashion. This in turn resulted in tensional stresses in the crust, which were relieved by the injection of the Karroo dolerites. du Toit suggests that the relative order of injection was from the summit downwards (1920, p. 33). Elsewhere, the present author found evidence in support of this theory (1943, p. 107). A process of gradual uplift, concomitant with magmatic intrusion, and causing stresses at progressively lower levels, would indeed have a downward order of injection as a direct inference.

The main period of dike injection followed that of the sheets. Within and around Basutoland the trend of the dikes is most commonly west-north-west, with a poorer developed set at right angles thereto. Evidently the injection of the dikes represents the culmination of the process of uplift described above. The west-north-westerly direction of the dominant dike swarm probably coincides with the direction of the longer axis of the parent subjacent intrusion.

Confining ourselves to Mount Arthur, it is clear that the upsurge of the magma was mainly controlled by negative hydrostatic pressure, causing "stoping, and the sucking-up or drawing-up of magma into potential vacua within the crust" (van Bemmelen, 1936, p. 490).

* Personal communication.

Anderson (1924, p. 11) evolved a dynamic theory to account for the formation of cone-sheets and ring-dikes of Mull. He found that an increase of pressure in a magma reservoir of roughly paraboloid shape would produce strains in the roof. Such strains would then be relieved by cone-fracturing. The reverse is equally true, and thus a decrease in pressure would produce outwardly inclined fractures, resulting in ring-dikes and outwardly transgressive sheets or "inverted cone-sheets", such as occur at Mount Arthur.

It is not improbable that the collapse of the roof produced a caldera on the surface. Subsequent erosion removed the entire summit of the complex, and no evidence of volcanic activity could be found at lower levels.

The various stages in the formation of the complex may thus be summarised as follows:—

1. Development of a ring-fissure and injection of the earlier tholeiite magma along the fracture.

2. Subsidence of the central block and simultaneous emplacement of the olivine-dolerite magma in the potential vacuum created by the subsidence.

3. Collapse of the roof and the engulfment of great blocks of Stormberg sediments by the magma. Caldera formation on the surface?

4. Resurgence of volatiles from the included sediments and consequent formation of a highly mobile tholeiite magma. Gradual sinking of the sediment in the modified magma.

5. Upward migration of the volatiles. Subcrustal spreading of the tholeiite magma, controlled by negative hydrostatic pressure, and producing "inverted cone-sheets".

6. Consolidation of the magma.

7. Final relief of tensional stresses by later intrusions of dolerite as sheets and dikes.

These relations are further illustrated in Fig. 10.

VII. Conclusions.

The study of the Mount Arthur complex yielded the following conclusions:—

1. The complex has the shape of a plug or stock; widening downwards.

2. It was formed by the subsidence of a block of sediment, enclosed within an earlier ring-dike.

3. A first intrusion of tholeiite magma along the ring-dike was followed by the upsurge of a large volume of olivine-dolerite magma.

4. The olivine-dolerite magma was identical to the magma which caused the intrusions of Elephant's Head, New Amalfi, and Insizwa.

5. Collapse of the roof resulted in the engulfment of large blocks of Stormberg sediments by the magma.

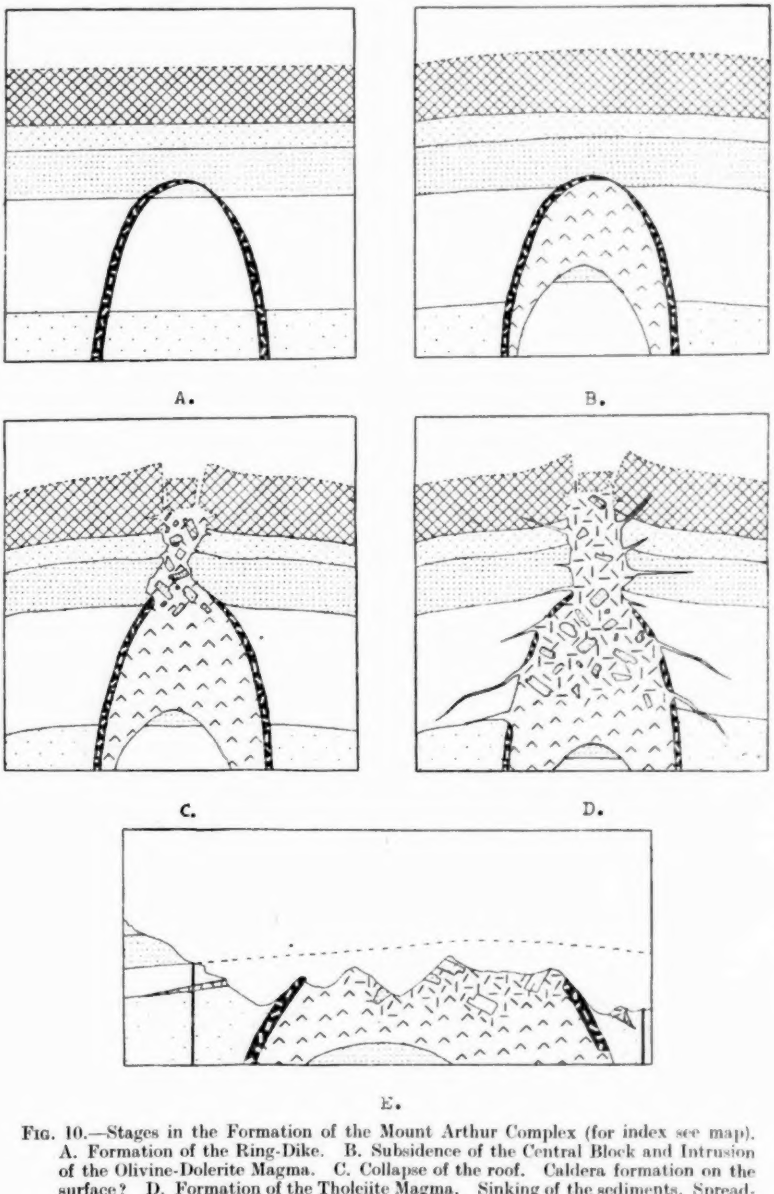

FIG. 10.—Stages in the Formation of the Mount Arthur Complex (for index see map). A. Formation of the Ring-Dike. B. Subsidence of the Central Block and Intrusion of the Olivine-Dolerite Magma. C. Collapse of the roof. Caldera formation on the surface? D. Formation of the Tholeiite Magma. Sinking of the sediments. Spreading of the Tholeiitic Magma. E. East-West section through the Complex with present surface.

6. The connate waters of the sediments acquired resurgent properties upon immersion in the magma. The resurgent gases were incorporated by the magma and caused the conversion of part of the olivine-dolerites to tholeiites.

7. The specific gravity of the magma in the vicinity of the sediments was sufficiently lowered by the resurgent volatiles to enable the xenoliths to sink. Subsidence was further promoted by the "drag" caused by the foundering of the central block.

8. Later magmatic activity is evidenced by thin sheets and dikes, occupied by dolerites of the B.K. type of Karroo dolerite.

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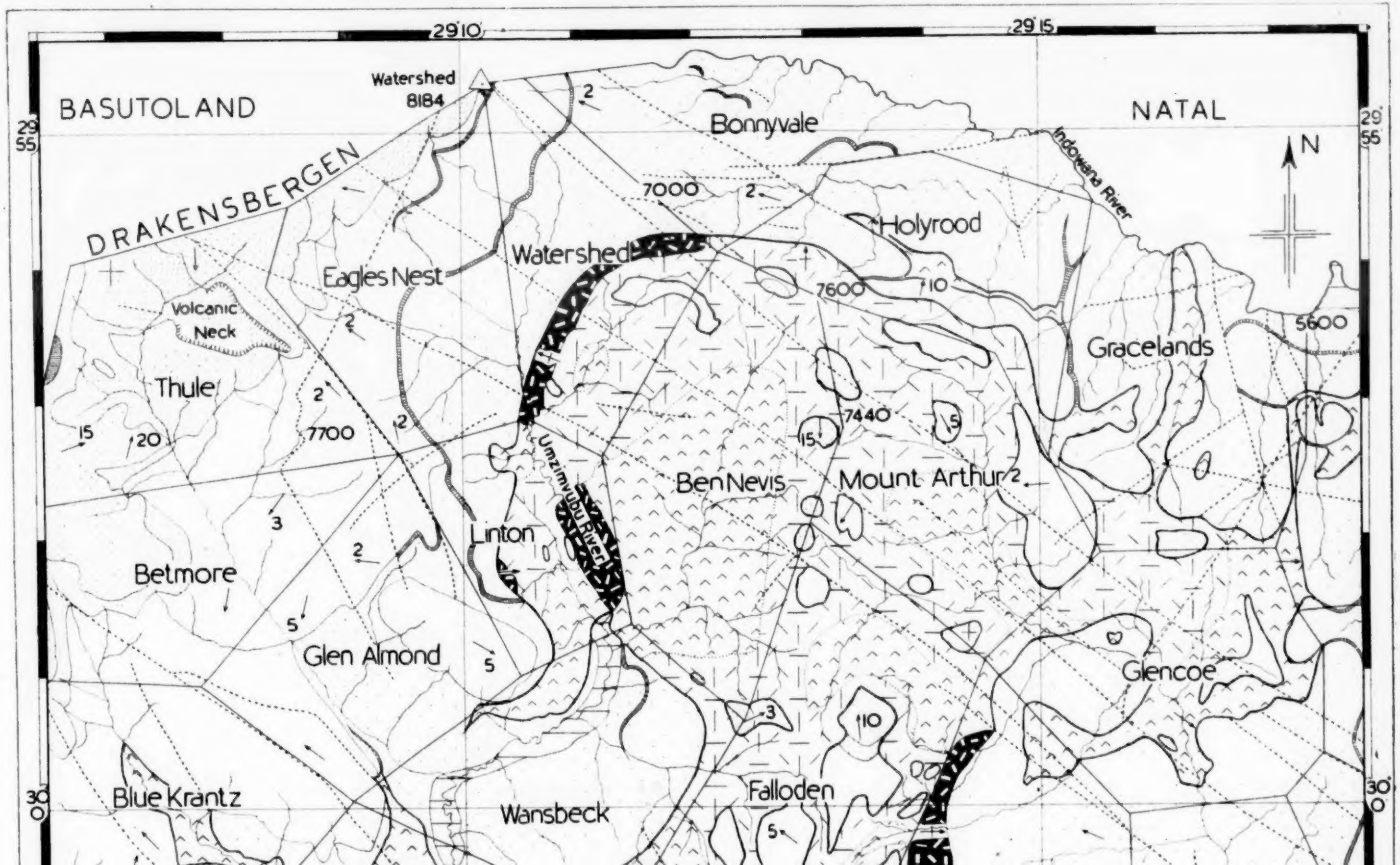
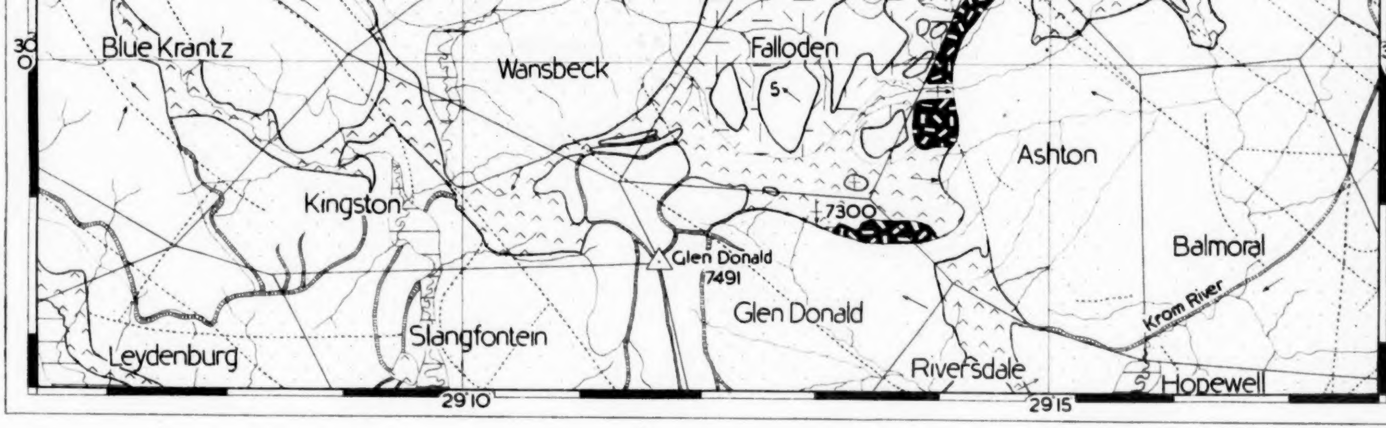
GEOLOGICAL MAP OF THE MOUNT ARTHUR COMPLEX (MOUNT CURRIE).





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SCALE

0 1 2 3 4 Miles

Drakensberg Lavas

Cave Sandstone.

Red Beds

Molteno Beds.

Stormberg Series.

Upper Beaufort or Burghersdorp Beds.
(Beaufort Series)

A. Poldervaart.

Neill & Co., Ltd.

CAPE CHEMICAL SOCIETY
MARLOTH MEMORIAL

THE ESSENTIAL OIL OF *AGATHOSMA APICULATA* MEYER.

By J. L. B. Smith and D. E. A. Rivett.

(Read March 15, 1944.*)

Prominent among the herbal remedies employed by the rural populace of South Africa are the various plants designated broadly as "Buchu". Chiefly these are members of the large family RUTACEAE, of which many representatives, chiefly endemic species and many endemic genera, occur in South Africa. One of the characters of this family is that all, or almost all, of the species secrete essential oil, usually concentrated in special glands in the leaf, often visible and apparently exsert from the lower surface.

Much of the reputed medicinal value of these plants is attributed to the essential oil they contain. Generally an infusion of the dried leaves is employed, and this from our observation may contain much or little of the oil according to the manner of its preparation. Since from our determinations it appears that the leaves always lose a considerable portion of the more volatile components of the oil on drying, it may be presumed that those, often terpenes, are not the portion of major clinical importance. It is possible that the pungent odour of the leaves and of the infusions prepared from them have in the case of some plants at least been responsible for inducing in the credulous an exaggerated belief in their curative properties.

The purely endemic genus *Agathosma* Willd. occurs from the south-west Cape to the Bashee, with greatest concentration of species near the Cape. *Agathosma apiculata* G. F. Meyer is a much branched woody shrub attaining in favourable situations a height of 4 feet, though generally smaller and stunted. The leaves are small, about 4–5 mm. in length and 1–1·5 mm. in width, fairly fleshy, closely packed on and firmly adherent to the branches and twigs. Oil glands are plainly visible in the lower surface of the leaf.

* This paper was selected for publication in 1945 under the Marloth Memorial Fund, established in memory of the late Dr. R. Marloth, Chemist and Botanist.—Editor.

This plant extends from Still Bay to the Kowie River at Port Alfred, *i.e.* from 21° 30′ to 26° 50′ E. Its occurrence in fair quantity in healthy growth almost to the west bank of the river and its apparently complete absence from the similar area eastwards across the river is noteworthy.

(It may be significant that the tick *Rhiticephalus sps.*, which carries East Coast Fever, does not extend westwards of the Kowie River.)

A. apiculata grows in dune sand usually in a rather restricted area on the landward side of the dunes, usually under some shelter from scrub or bush against the direct blast of the wind from the sea. When this plant colonises wind-swept cliffs it is dwarfed almost beyond recognition to a small disc flat on the ground, with the leaves abnormally and densely packed on the closely interwoven twigs. At Knysna the plant extends inland along the banks of the estuary in sheltered sites, and is found also on an island near the mouth of the river, but only where typical dune sand exists. When crushed the leaves emit a powerful and rapidly nauseating odour. On warm days this is quite strong wherever there is any concentration of the plant. A characteristic aromatic odour of the summer sea breeze of the southern Cape may be attributed to the oil of this plant.

A. apiculata is not very well known, but generally bears the name of "Sea-Buchu". By the natives of the coastal belt of the south-eastern Cape it is termed "e-Buchu" and esteemed as a febrifuge and stomachic. The infusion employed is stated to induce a profuse perspiration. Although we have not put this to a personal test, after much experience in handling the plant and its oil we do not doubt that it possesses this property.

It has several times been noted that the oil content of plants shows a seasonal variation, being highest in winter.*

Since the present investigation was performed with material collected from March to August, it has not been possible to establish this variation in *A. apiculata*. Over this period the yield of oil was fairly constantly 0·32 per cent., based on the fresh leaves. At the same time it has been found that the composition of the oil varies considerably according to the time of the year at which the plant is harvested. It so happens that this may easily be determined from the optical rotation alone. In August the more volatile components of the oil are present in considerably greater proportion than in March. Also it has been found that when dried in air the leaves lose a considerable proportion of the oil, especially of the more volatile part.

* Smith and Elliott, "The Essential Oil of *Agathosma microphylla*", Trans. Roy. Soc. S. Africa, xvii, 23, 1928; Bogart and Marion, "The Oil of *Sarothra gentianoides*", J.A.C.S., **55**, 4188, 1933.

Among Rutaceous plants of whose oils we have seen the stated compositions, *A. apiculata* is unique in that its oil has now been found to contain a relatively high proportion of sulphur.

Extracted by exhaustive distillation with steam from the fresh leaves and tops collected in March, the dry oil has the following composition: 72·2 per cent. *C*, 10·1 per cent. *H*, 6·7 per cent. *O*, and 11·0 per cent. *S*.

Physical constants of the oil are as follows:—

	Oil from fresh leaves collected in *March* 1943.	*August* 1943.
d^{25}_{25}	0·890	0·888
N^{20}_{D}. . . .	1·4841	1·4837
$(\alpha)^{19}_{D}$	−5·1	−8·27
Sulphur content .	11·0 per cent.	8·4 per cent.

For oil obtained from air-dried leaves collected in May:

d^{25}_{25}	0·906
N^{20}_{D}	1·4853
$(\alpha)^{15}_{D}$	−0·66
Sulphur content . .	12·9 per cent.

94 per cent. of the oil distils over at 155–225° C. (730 mm.), with obvious maxima about 163° and 215°, the residue being dark and resinous.

The oil possesses a pungent and nauseating odour which clings tenaciously. It penetrates the skin with ease and is removed with difficulty. These properties have rendered the investigation at times exceedingly unpleasant, all the more so since degradation products almost always contained substances of appalling odour and relatively high toxicity.

When preserved in well-sealed containers the oil shows no marked change, but when kept where air has access a clear resin deposits after some months.

The oil exhibits a high degree of unsaturation. Its main components are:

1. *l-β-pinene*, a compound but seldom reported as occurring in plants of South Africa (25 per cent.).
2. A terpene of uncertain identity of boiling-point 171–173° C. at 730 mm. (8 per cent.).
3. *Butyl*-1-*pentenyl disulphide*, $C_9H_{18}S_2$, a substance not previously reported in chemical literature (30 per cent.).
4. A liquid compound $C_{10}H_{16}O_2$, which may be a hexadienyl ester of *n*-butyric acid (30 per cent.).

5. Undetermined resinous matter (7 per cent.).
6. A minute amount of free, probably *n*-butyric, acid.

Aromatic compounds appear to be absent. Phenols and phenol ethers if present only in very minute amount.

The terpene content is highest at the end of the winter, while air-dried leaves contain very little of this component.

Experimental.

The separated leaves and twigs were treated in 20-lb. lots with steam in a galvanized iron still 5 feet high and 10 inches in diameter. The distillate tended to emulsify, and separation of the oil was facilitated by the addition of sodium chloride.

The leaves yielded an average of 0·32 per cent. of oil. Leaves collected in May and air-dried yielded only 0·31 per cent. of oil. The oil so obtained is almost colourless, but darkens slightly on standing. It possesses a powerful penetrating and nauseating odour and high penetrative power. From the skin it may be removed only by drastic treatment, permanganate or hypochlorites proving effective.

Elements.

Qualitative tests showed the presence of sulphur. Quantitative analysis established the presence of oxygen also.

Acids: Phenols.

The oil showed a neutral reaction. The alkali extract of 60 gm. of the original oil when acidified yielded 0·1 gm. of an ether soluble semisolid mass with acid reaction, obviously a mixture, possessing a pungent rancid odour in which that of butyric acid was clearly discernible. No definite proof of the presence of any of the commoner phenols or of any aromatic acid could be obtained.

Unsaturation.

Neutral 5 per cent. $KMnO_4$ solution was almost instantaneously decolorised in the cold by the oil. Bromine was instantly absorbed, also hydrobromic acid, but no crystalline products could in either case be isolated.

Oxidation Products.

Both full and partial oxidation of the oil by means of permanganate were carried out. The oil was treated under reflux on the water-bath with seven times its weight of $KMnO_4$ added in portions. The residual solution freed from MnO_2 was extracted with ether. The alkaline aqueous

solution remaining after ether extraction was acidified and extracted with ether. The ethereal extract on evaporation left a liquid acidic residue in which acetic acid, propionic acid, and *n*-butyric acid could be identified. The acid aqueous solution remaining after ether extraction was found to contain these acids, carbon dioxide, sulphuric acid, and oxalic acid.

When the oil was treated similarly, but at 0° C. with alkaline $KMnO_4$ (4 gm. for 1 gm. oil), the same products were found, together with a large amount of formic acid. All attempts to prepare a sulphonic acid by oxidation of the oil proved fruitless.

Phenol Ethers.

The ordinary method for Zeisel estimation is generally accepted as liable to some error. When this estimation was performed with the original oil very considerable silver sulphide formed in the absorption flasks. After removal of this there remained AgI and some sulphur. The AgI of several estimations was equivalent to $-OCH_3 = 1$ per cent. $\pm 0{\cdot}2$. Little significance is attached to this result. All attempts to isolate any solid acid such as anisic acid as an oxidation product of the oil proved fruitless.

Iodine Value.

No constant value for this could be attained. The iodine value increased with time of reaction, values of over 500 being obtained after 5 hours. This inconstancy may be attributed to the presence of the disulphide.

Saponification Value.

In this case also no reliable figure could be obtained. The disulphide present obviously reacts with alkali. When the alkaline solution was acidified after reaction evil smelling substances were liberated. It was thus useless to attempt to obtain acetyl values or to evaluate alcohols by acylation methods.

Reaction with Alkyl Iodides.

When the oil (4 gm.) was heated with an equal volume of methyl iodide in a sealed tube in boiling water, after 48 hours small colourless apparently cubic crystals commenced to deposit. These slowly increased in amount, while simultaneously iodine was set free and dark oily matter separated. After three weeks of reaction from the contents of the tube was isolated only 0·2 gm. of a light yellow crystalline solid which twice recrystallised from methanol melted sharply at 195° C. Found: $I = 62{\cdot}23$ per cent.; $(CH_3)_3SI$ required $I = 62{\cdot}24$ per cent. Melting-points of

trimethylsulphonium iodide reported in chemical literature vary from 184–210° C.

A similar result was obtained with benzyl iodide, only a small amount of tribenzylsulphonium iodide being obtained.

When the oil (3·0 gm.) was left overnight with mercuric iodide (6·9 gm.) and benzyl iodide (6·6 gm.) in acetone (15 ml.) crystals formed (0·05 gm.). After recrystallisation from an acetone-ether mixture these melted sharply at 136° C. Haas and Dougherty (J.A.C.S., **62**, 1004, 1940) state that the tribenzylsulphonium iodide-mercuric iodide complex melts at 136–137° C.

These results indicate an absence of the normal reaction between a disulphide and alkyl iodide, and point to some source of a small amount of free sulphur in the oil (see Zeisel estimation *above*, and action of Zinc dust *below*).

Aldehydes and Ketones.

Both with the original oil and with various fractions prolonged treatment with concentrated sodium bisulphite solution gave no result. No product could be isolated by treatment with semicarbazide. The oil showed no trace of reducing power with the ordinary reagents, nor did it give any colour reaction characteristic of ketones. Aldehydes and ketones are thus taken to be absent.

Effect of Cold.

A sample of the original oil kept at $-10°$ C. for six weeks showed no change and deposited no crystals. Under these conditions any Diosphenol present would almost certainly have separated out.

Action of Mercuric Chloride Solution.

In an attempt to separate the sulphur compounds the oil (6 gm.) was added to 150 ml. of a 5 per cent. solution of mercuric chloride. On shaking the oil became more viscous and acquired a density greater than before since it rapidly settled out. There was, however, even after prolonged treatment no sign of any formation of solid matter, nor could any separation be effected. Distillation with steam of the heavy product merely returned the original oil unchanged.

Behaviour on Distillation.

In a preliminary trial distillation at the ordinary pressure (715 mm.) the oil commenced to boil at 155° and showed a marked maximum at 161–165°. Thereafter the temperature rose steadily and uniformly until a definite maximum occurred at 205–220°, with little distillate and little residue above that temperature. As some degree of decomposition was

evident during the latter stages of this distillation, the main portion of the oil (300 gm.) was subjected to repeated fractionation *in vacuo* in a current of carbon dioxide. In this fashion there were finally obtained at 14 mm. pressure the following fractions:—

	Temp. ° C.	Per Cent. Original Oil.	Per Cent. Oil per Degree.
Fraction I . . .	65–70	28·0	5·6
Fraction II . . .	70–95	32·5	1·3
Fraction III . . .	95–107	29·5	2·5
Fraction IV . . .	107–125	4·0	0·2
Gummy Residue . .	. .	6·0	

Fraction I: Isolation of β-Pinene.

This fraction was found to contain 85·5 per cent. *C*, 11·6 per cent. *H*, and 2·9 per cent. *O*. It was obviously a mixture (see p. 122) from its odour, containing terpenes. The whole amount (84 gm.) was therefore refluxed with 6 gm. sodium wire on a water-bath for 24 hours when a slow reaction with production of solid occurred. The decanted oil was distilled *in vacuo* over sodium. The distillate again heated with sodium and finally distilled over sodium at the ordinary pressure (715 mm.) gave a colourless oil (52 gm.), boiling at 159–166° C. This was redistilled over sodium and the portion (28 gm.), boiling at the maximum 161–163° C., collected separately.

Found: $C = 88{\cdot}12$ per cent., $H = 12{\cdot}07$ per cent., $C_{10}H_{16}$ requires $C = 88{\cdot}24$ per cent. and $H = 11{\cdot}76$ per cent.

No solid addition product of this oil could be obtained. With bromine, hydrochloric acid, nitrosyl chloride, and nitrous fumes it reacted, but in each case the product was liquid, and could not be induced to yield any crystalline portion.

Uncontrolled oxidation yielded considerable oxalic acid and carbon dioxide, together with aliphatic acids. Carefully controlled oxidation by permanganate with caustic soda at 0° C. resulted in the isolation from the solution of a relatively insoluble sodium salt. This by treatment with slight excess of hydrochloric acid yielded a crystalline acid, which melted at 126° C. Found: $E = 184$. Nopinic acid melts at 126° and has $E = 184$. No specimen of Nopinic acid was available for comparison, nor could we obtain any by oxidation of a so-called turpentine-oil. There is, however, little doubt of its identity, and the relatively insoluble sodium salt is characteristic.

When this terpene was subjected to the action of dilute sulphuric acid for three weeks it first gave Terpineol, and was finally all converted into

the solid Terpin Hydrate. This was almost quantitative, and established the presence of *β-pinene* as the only terpene in this region.

Physical constants were:

Found:

$$N_D^{25} = 1{\cdot}4734; \quad d_{25}^{25} = 0{\cdot}853; \quad (\alpha)_D^{25} = -25{\cdot}5.$$

1-β-pinene requires:

$$N_D^{22} = 1{\cdot}4724 \text{ to } 1{\cdot}4749; \quad d_{22}^{22} = 0{\cdot}866 \text{ to } 0{\cdot}8675; \quad (\alpha)_D = -25{\cdot}49 \text{ to } -25{\cdot}75$$

(Wallach, A., **363**, 10 (1908)).

It is but seldom that this terpene has been reported in plants occurring in South Africa.

Fraction II: 70–95° *C. at* 14 *mm.*

Exhaustive refractionation gave no evidence of any maximum with this sample. It was obviously a mixture (see p. 123), that portion boiling below 85° C. (14 mm.) contained only a trace of sulphur. Aldehydes and ketones were found absent.

The middle portion of this fraction was found to contain 81·0 per cent. *C*, 11·0 per cent. *H*, and 8·0 per cent. *O*. When a portion of this fraction was treated with sodium wire in absolute ether solution, a vigorous reaction occurred with production of a brownish solid. After heating to complete the reaction the solid was separated from the ethereal solution which was retained (see below). The solid, which was found to contain sodium butyrate, was brought to reaction with phthalic anhydride. The product was hydrolysed and steam distilled, but from the distillate only a minute amount of resinous matter could be extracted by ether. It is thus presumed that alcohols were absent.

The ethereal solution (above) when evaporated left a dark resinous oil which when distilled at 730 mm. gave 3·2 gm. of a colourless oil boiling at 171–173° C. This had an odour strongly reminiscent of Limonene, and gave no crystalline addition product with hydrochloric acid. Owing to circumstances it was not found possible to investigate this further.

Fraction III: 95–107° *C. at* 14 *mm.*

Repeated refractionation of this fraction *in vacuo* in a current of carbon dioxide yielded finally Fraction IIIA, taken at 100–101° C. at 17 mm., in amount equivalent to 10 per cent. of the original oil. This had a most unpleasant clinging odour. It contained the following: 64·0 per cent. *C*, 9·5 per cent. *H*, 9·4 per cent. *O*, and 17·1 per cent. *S*. It was thus almost certainly a mixture and appeared to be an azeotrope, since further distillation produced no change. Physical constants of Fraction IIIA were:

$$N_D^{20} = 1{\cdot}4854; \quad d_{20}^{20} = 0{\cdot}934; \quad (\alpha)_D^{20} = +0{\cdot}45.$$

In reaction with methyl iodide and with benzyl iodide this fraction gave the same results as the original oil. Reaction was more rapid, but in each case the product was as before, being what might be expected if the oil contained merely a small amount of free sulphur.

An attempt to bring about scission of the disulphide by means of alcoholic potassium sulphide was without result.

When 10 ml. of Fraction IIIA was refluxed over zinc dust under carbon dioxide there was no discernible change in the boiling-point of the oil after even 10 hours of boiling. At the same time the zinc was subsequently found to have removed from the oil a small amount (undetermined) of sulphur.

When Fraction IIIA was completely oxidised by alkaline permanganate, the products were carbon dioxide, oxalic acid, much *n*-butyric acid, and sulphuric acid. Attempts to prepare a sulphonic acid by oxidation proved fruitless.

It may be noted that the chemistry of the unsaturated disulphides appears to be poorly known and should prove a fruitful field for investigation.

Isolation of the Disulphide.

Isolation of the disulphide present in this Fraction IIIA was finally accomplished by scission with metallic sodium into its component units and recombination of those by means of reaction with iodine.

Fraction IIIA (20 gm.) in solution in anhydrous ether (40 ml.) in a flask fitted with inverted condenser was cooled in ice. Sodium wire (3 gm.) was carefully introduced, when reaction without evolution of hydrogen commenced almost immediately and increased so rapidly in vigour as to need drastic cooling for control. The solution darkened in colour and solid matter separated. The flask was finally heated on the water-bath for an hour to complete the reaction. The solution when centrifuged yielded a light yellow-brown solid, which was triturated with more ether and again centrifuged. The separated ethereal solutions when evaporated left a semisolid residue which appeared to contain chiefly resinous matter and was discarded.

The separated sodium salts were freed from ether in a high vacuum at the ordinary temperature. 4·0 gm. of the sodium salts so obtained was dissolved in 50 ml. water, the solution filtered and extracted three times with ether. The filtered aqueous solution was treated with a slight excess of strong aqueous iodine solution, when a colourless oil separated. This was extracted with ether, the ethereal extract dried over anhydrous sodium sulphate and evaporated. There remained 0·5 gm. of a light brown oil which possessed the nauseating and penetrating odour of Fraction IIIA.

Found: 56·72 per cent. *C*, 9·49 per cent. *H*, and 33·72 per cent. *S*. $C_9H_{18}S_2$ requires 56·83 per cent. *C*, 9·49 per cent. *H*, and 33·68 per cent. *S*.

It is clearly without significance that this resynthesised product was likely not to have been the single compound $C_9H_{18}S_2$, but from the manner of its formation to have contained in addition the compounds R_2S_2 and R'_2S_2, where $R + R' = C_9H_{18}$. An oil of the composition obtained ($C_9H_{18}S_2$) could have resulted from the action of iodine on RSNa and R'SNa ($R + R' = C_9H_{18}$) only if those were present in exactly equimolecular proportions in the mercaptide preparation. A mercaptide mixture of such proportionality could have resulted only from the action of sodium on either RSSR' alone, or on exactly equimolecular proportions of RSSR and R'SSR' in the Fraction IIIA. The latter is of itself so remote a possibility that it need scarcely be considered. RSSR and R'SSR' may in any case be expected to have different boiling-points and would not be likely to yield a maximum distillate of so unusual a composition especially as an oxygenated compound is also present in Fraction IIIA (see p. 122).

It may therefore be concluded that the original oil contains the disulphide $C_9H_{18}S_2$. It is apparently the only sulphur compound present in the oil of *A. apiculata*.

Correlating the sulphur content (8·4 per cent.) of the original oil obtained from the plant collected in August it follows that that oil contained 25 per cent. of the compound $C_9H_{18}S_2$ ($S = 33·7$ per cent.), whereas oil from the leaves collected in March (11·0 per cent. *S*) contained 33 per cent. of it.

Structure of the Disulphide.

Using the crude sodium mercaptide prepared by the action of sodium on Fraction IIIA, attempts were made to prepare the Lead and Mercury mercaptides. A Lead mercaptide was obtained only as a rapidly decomposing resinous mass containing Lead sulphide, and it resisted all attempts at isolation in any other form. A Mercury mercaptide was obtained in the form of fine needles melting at 64·5°, but no satisfactory method for its analysis with the means at our disposal could be devised.

Pentenyl-2-4-Dinitrophenyl Sulphide.

When the crude sodium mercaptide preparation obtained from Fraction IIIA was brought to reaction under varying conditions with 2-4-dinitrochlorobenzene, the chief product was *bis*-(2-4-dinitrophenyl) sulphide (I). Among the yellow crystals of this appeared several times small amounts of brownish crystals which when isolated appeared obviously different from the main reaction product. Eventually by fractional crystallisation,

(I) $(2\text{-}4\text{-}(NO_2)_2C_6H_3)_2S$ (II) $2\text{-}4\text{-}(NO_2)_2C_6H_3—S—C_5H_9$,

pentenyl-2-4-dinitrophenyl sulphide (II) was isolated in quantity sufficient to establish its identity. Obtained in the form of golden yellow needles it melted at 79·5° C.

Found: $C = 49{\cdot}27$ per cent., $H = 4{\cdot}45$ per cent., $S = 11{\cdot}86$ per cent. $C_{11}H_{12}O_4N_2S$ requires $C = 49{\cdot}26$ per cent., $H = 4{\cdot}48$ per cent., $S = 11{\cdot}94$ per cent.

This compound has not previously been reported in chemical literature.

This crucial evidence establishes the disulphide as a butyl pentenyl disulphide.

An attempt to oxidise the pentenyl dinitrophenyl sulphide to the corresponding sulphone was unsuccessful. In both this reaction and in the oxidation to sulphonic acids, the unsaturated sulphur compounds behave aberrantly almost as if the degree of unsaturation in the carbon chains were enhanced.

The following summarises the evidence and the manner in which it may be employed to solve the problem of the structure of the disulphide $C_9H_{18}S_2$:—

1. It contains the pentenyl and the butyl groups.
2. On oxidation it yields one or more of carbon dioxide, oxalic acid, *n*-butyric acid, and sulphuric acid, very little if any sulphonic acid.
3. It appears to yield a trace of sulphur to reagents such as zinc dust and alkyl iodides.

The disulphide is therefore $C_4H_9—S—S—C_5H_9$. The butyl group cannot be other than normal, since no aliphatic acid but *n*-butyric acid is obtained on oxidation. For the same reason the pentenyl group must be 1-pentenyl–, *i.e.* $CH_3—CH_2—CH_2—CH{=}CH—$. The oxalic acid found among the oxidation products cannot originate from the disulphide, but must have come from the oxygenated compound described below.

The small positive rotation of Fraction IIIA is also likely due to this oxygenated compound, since there is no asymmetric disulphide of formula $C_4H_9—S—S—C_5H_9$ which could yield only the oxidation products found. The disulphide may thus with reasonable certainty be accepted as *Butyl*-1-*Pentenyl Disulphide*, *i.e.*

$$CH_3.CH_2.CH_2.CH_2.S.S.CH{=}CH.CH_2.CH_2.CH_3.$$

Other Components of the Sodium Mercaptide Product.

Attempts were made to isolate the actual butyl and pentenyl mercaptans themselves from the crude mercaptide preparation (obtained by

the action of sodium on Fraction IIIA). Owing partly to the relatively limited amounts of material available, partly to the devastating effects of the slightest inhalation of the vapour of the liberated compounds, and partly to the obviously unstable nature of a portion of the product these were not pursued. It was, however, definitely established that a very considerable proportion of the crude mercaptide product consisted of sodium *n*-butyrate. This is important, since that salt could in no fashion have been produced by the action of sodium on the disulphide (above). It must therefore have come from the oxygenated compound present (*q.v.*) with the disulphide in Fraction IIIA.

Oxygenated Component of Fraction IIIA.

Fraction IIIA (p. 118) was found to contain: 64·0 per cent. *C*, 9·5 per cent. *H*, 9·4 per cent. *O*, and 17·1 per cent. *S*. The latter as $C_9H_{18}S_2$ (33·7 per cent. *S*) thus comprises 51 per cent. of Fraction IIIA. Brief analysis of these figures shows that a mixture of 51 per cent. $C_9H_{18}S_2$ and 49 per cent. $C_{10}H_{16}O_2$ will contain: 64 per cent. *C*, 9·5 per cent. *H*, 9·4 per cent. *O*, and 17·1 per cent. *S*. Repetition of values found: 64·0 per cent. *C*, 9·5 per cent. *H*, 9·4 per cent. *O*, 17·1 per cent. *S*.

From the manner in which Fraction IIIA was obtained, it may be deduced that these figures point definitely to the presence of only the single compound $C_{10}H_{16}O_2$ with the disulphide in Fraction IIIA. It is extremely unlikely that exactly equimolecular proportions of say $C_{10}H_{16}O$ and $C_{10}H_{16}O_3$, still less of C_5— and C_{15}— could be present in Fraction IIIA.

Further confirmation that the compounds $C_9H_{18}S_2$ and $C_{10}H_{16}O_2$, and those two compounds only, occur in admixture in this temperature region was furnished by analysis of the oil which came over below Fraction IIIA during preparation of the latter from Fraction III. This was found to contain 64·4 per cent. *C*, 9·5 per cent. *H*, 9·7 per cent. *O*, and 16·4 per cent. *S*. A mixture of 48·7 per cent. $C_9H_{18}S_2$ and 51·3 per cent. $C_{10}H_{16}O_2$ would contain 64·4 per cent. *C*, 9·5 per cent. *H*, 9·7 per cent. *O*, and 16·4 per cent. *S*. This fraction showed a positive rotation slightly greater than that of Fraction IIIA, confirming the suggestion that the optical activity here lies with the compound $C_{10}H_{16}O_2$ rather than with the disulphide.

Further striking confirmation of the presence of the compound $C_{10}H_{16}O_2$ is to be found in the compositions of Fractions I and II. Thus Fraction I proves to be a mixture of 15 per cent. $C_{10}H_{16}O_2$ and 85 per cent. β-Pinene ($C_{10}H_{16}$), which would contain: $C=85·6$ per cent., $H=11·4$ per cent., $O=3·0$ per cent.

Found: $C=85·5$ per cent., $H=11·6$ per cent., $O=2·9$ per cent. (see p. 117).

The middle portion of Fraction II (p. 118) proves to be a mixture of

42 per cent. $C_{10}H_{16}O_2$ and 58 per cent. $C_{10}H_{16}$, which would contain: $C = 81{\cdot}1$ per cent., $H = 10{\cdot}8$ per cent., $O = 8{\cdot}1$ per cent.

Found: $C = 81{\cdot}0$ per cent., $H = 11{\cdot}0$ per cent., $O = 8{\cdot}0$ per cent. (see p. 118).

Even the isolation of the compound $C_{10}H_{16}O_2$ could scarcely afford stronger evidence of its presence in the oil than these and the other figures shown on p. 122.

That this compound $C_{10}H_{16}O_2$ can be Diosphenol is very doubtful. Not only does no solid separate when the oil is kept at a low temperature, but none of the easily isolable oxidation products of Diosphenol could be obtained in this case.

We have not been able to identify this compound $C_{10}H_{16}O_2$ with any known substance. It may be expected to have a boiling-point of about 190–200° C. (730 mm.) and $(\alpha)_D^{20}$ about $+1{\cdot}0$. It has been found to yield sodium *n*-butyrate by reaction with metallic sodium, while on oxidation it yields oxalic acid and one or both of butyric acid and carbon dioxide. It is very probably optically active. It is possible that it is an *n*-butyric ester, which under the conditions of reaction with sodium in this case undergoes scission to yield sodium butyrate. On this assumption it may be a hexadienyl ester of *n*-butyric acid. No available literature lists any known hexadienols, only certain acetylenic 6-carbon alcohols. None of the latter would yield the oxidation products obtained from the compound found in this oil. A possible structure for this compound is (III)

$$CH_2{=}CH{-}CH{=}CH{-}CH(CH_3){-}O{-}CO{-}C_3H_7$$

(III).

This would, however, yield on oxidation a small amount of acetic acid which we could not with certainty identify among the oxidation products.

There is little possibility from its high reactivity that the C_6H_9— group could in this case be cyclic. Compounds of that type should on oxidation yield easily identifiable solid acids which were not obtained.

Fraction IV. 107–125° *C. at* 14 *mm.*

From the slightly greenish colour and the odour of this fraction it was expected that sesquiterpenes might be present, but as it proved to react almost completely with metallic sodium, this was probably not the case. It probably contained the disulphide as well as some of the compound $C_{10}H_{16}O_2$. This fraction was not further investigated.

Non-volatile Residue.

This resinous matter was not fully investigated. It contained some sulphur, but was probably chiefly polymers of the unsaturated compounds present in the oil.

Clinical Properties.

This oil resembles in odour and somewhat in constitution oriental oil of Asafoetida, which is employed medicinally. It has not been found possible under present conditions to arrange for a clinical test with this oil, but it is hoped to report later on this matter. It is not unlikely that the oil of *Agathosma apiculata* may eventually replace the imported oriental product.

SUMMARY.

1. *Agathosma apiculata* Meyer, a coastal Rutaceous shrub, contains 0·32 per cent. of essential oil, the composition of which varies with the season, there being a higher proportion of the more volatile components in winter. The oil is unique among those of the RUTACEAE in containing about 10 per cent. of sulphur.

2. The main components of the oil are:

(*a*) About 25 per cent. of *laevo*-β-PINENE, a compound rare in South African plants.

(*b*) About 8 per cent. of a terpene of boiling-point 171–173° C. at 730 mm.; of uncertain identity.

(*c*) About 30 per cent. of a compound $C_{10}H_{16}O_2$ of uncertain identity, almost certainly aliphatic and possibly a hexadienyl butyrate.

(*d*) About 30 per cent. of *BUTYL*-1-*PENTENYL DISULPHIDE*, a compound not previously reported in chemical literature.

(*e*) About 7 per cent. of resinous matter, possibly polymers.

3. Aromatic compounds do not appear to be present in the oil.

The authors desire to express their gratitude to the National Research Board of South Africa for financial assistance which defrayed a part of the costs of the investigation.

RHODES UNIVERSITY COLLEGE,
GRAHAMSTOWN,
25th February 1944.

A LOWER BEAUFORT (KARROO) INVERTEBRATE FAUNA FROM SOUTHERN RHODESIA.

By Geoffrey Bond, F.G.S.

(Communicated by G. Arnold.)

(With Plate X.)

(Read October 18, 1944.)

Apart from plant remains, the Karroo rocks of Southern Rhodesia have so far yielded very few recognisable fossils. In 1903 Molyneux visited the Sengwe Coalfield and nearby areas and collected a few freshwater lamellibranchs and fossil fish. These were briefly described by Wheelton Hind and Smith Woodward (7). The horizon was given as Upper Matabola Beds, below the Escarpment Grits.

In the Short Report No. 26 of the Geological Survey of Southern Rhodesia, Maufe (6) describes the Karroo sequence in the Lower Inyantue Valley. He records and figures a specimen of *Archanodon subcastor* (Amal.) from the Madumabisa Shales, below the Escarpment Grits, indicating approximately the same horizon. The specimen was named by R. Bullen Newton.

Recently a visit was paid by Mr. A. M. Macgregor of the Geological Survey to the Sesame Valley in the Sebungwe District. He collected a considerable amount of fossiliferous material near Madziwadzido Native Department Camp which he very kindly sent to me for determination. In view of the scarcity of fossils recorded from the Karroo of Southern Rhodesia and in spite of the indifferent state of preservation of the material, it seems desirable to place on record an account of this fauna, particularly as it includes forms new to Southern Rhodesia which give further evidence for correlation with fossiliferous Karroo horizons in other South African territories.

The material contains abundant remains of non-marine Lamellibranchs, and the slabs are often crowded with a small Ostracod. There are also numerous fish scales, a single fin-spine, and obscure plant remains. The matrix consists of calcareous mudstone, with a poorly developed shaly parting.

Lamellibranchia.

Identification is hampered by the crushed and fragmentary nature of much of the material. Many specimens are casts. The forms present are certainly referable to the genera *Palaeomutela* Amal. and *Palaeanodonta* Amal. The distinction between them is based upon hinge characters, *Palaeanodonta* being edentulate, while *Palaeomutela* has irregular pseudotaxodont teeth. External form largely determines the species of the two genera. Hinge characters are only rarely, and then indistinctly, seen in the present material, but an attempt has been made to distinguish the forms by their external characters. A large number of "species" of these two genera has been described in the past, based on South African and Russian material. Cox in 1932 and 1936 reconsidered these "species" and relegated many of them to synonomy in a few well-defined species groups, with considerable variation in each group. He was then describing the Tanganyika fauna. In dealing with the Southern Rhodesian forms, which very closely resemble those from Tanganyika, Cox's broad conception of these species has been very largely followed. Nevertheless, it will probably be found when more material in a better state of preservation is assembled, that even these species may need revision. It must be understood, therefore, that the specific names which follow are used, for convenience, in a descriptive sense, and that their value as specific determinations may often be doubtful. The generic distinction between *Palaeanodonta* and *Palaeomutela* is probably well founded, but owing to restricted photographic facilities in war time, the fauna can only be adequately described by comparison with published figures. Direct comparison with Molyneux's duplicates from Southern Rhodesia and with Tanganyika and South African forms has been made from material in the collections of the National Museum of Southern Rhodesia, Bulawayo, and of the South African Museum in Cape Town, and agreement is very close indeed.

Since returning to England I have, through the kindness of Dr. L. R. Cox of the Natural History Museum, South Kensington, been able to see many of Amalitsky's South African and Russian specimens of Karroo and Permian non-marine lamellibranchs, also the original specimens of Molyneux (7) and the collections from Tanganyika described by Cox (1, 2). There is also a small collection of specimens presented by the Southern Rhodesia Geological Survey from Madziwadzido. This visit has considerably strengthened my faith in the close relationship between this Southern Rhodesian fauna and its equivalents in Tanganyika and South Africa. Recent Russian publications have, however, created even more difficulties in nomenclature, and have further emphasised the need for a full revision of the group before specific names can be applied with any confidence.

FAMILY CARBONICOLIDAE. Cox, 1932.

Genus PALAEOMUTELA. Amalitsky, 1892.

Palaeomutela neglecta (Jones).

This species was found by Molyneux (1903), and recorded as *P. keyserlingi* by Hind. Cox (1) has shown that this is synonymous with *Palaeomutela* (*Cyrena*) *neglecta* (Jones), and it must, therefore, be recorded as such. Molyneux's duplicates and one left valve in the Survey Collection agree with Cox's figures and revised description.

Palaeomutela rectodonta Amalitsky (Fig. 1, Pl. X).

One right valve from the Survey Collection seems to be specifically identical with the Tanganyika form figured and described by Cox, and agrees with specimens of this species from South Africa.

Genus PALAEANODONTA Amalitsky. 1895.

Palaeanodonta wadei Cox (Fig. 2, Pl. X).

Four left valves agree in all but size with Cox's (2) figures and descriptions of this species. The Southern Rhodesian specimens are smaller than the Tanganyika form, some specimens of which are preserved in the Rhodesian Museum Collection. Direct comparison is hampered by the different mode of preservation. The Tanganyika forms are crushed in black shale, those from Southern Rhodesia are fully inflated, but it is noteworthy that the ostracod *Darwinula globosa* var. *stricta* occurs with this species from both localities.

Palaeanodonta parallela (Amal.).

Three right valves, one left valve, and one pair of valves in the position of life are referred to this species. The characteristic ridge from umbo and posteroventral margin is not well developed, but the shell is often missing in this area. These forms lie within the limits of the species group of *P. castor* as defined by Cox and approach most nearly to *P. parallela*.

Palaeanodonta castor (Eichw.).

Three specimens are referred to this species. There are, in addition, several impressions of pairs of valves opened before burial by the contraction of the ligament but still lying umbo to umbo, which probably belong here, and indicate the slow accumulation of the enclosing sediment.

Palaeanodonta subcastor (Amal.) (Fig. 3, Pl. X).

Several specimens are referred to this species which is an important one in correlation. The specimen from the Inyantue Valley figured in

Short Report No. 26 (6), and named *Archanodon subcastor* (Amal.) by R. Bullen Newton, almost certainly belongs here. The name *Archanodon subcastor* is of very doubtful validity, and should almost certainly read *Palaeanodonta subcastor* (Amal.). I can find no reference to *A. subcastor* in the Zoological Record from 1895 to the present day, and there seem to be no adequate grounds for transferring the species to the genus *Archanodon.* I can only think that the two generic names have accidentally been confused. The figure given agrees in all essentials with Amalitsky's (1895) and Cox's (1936) figures of this species.

Ostracoda.

Darwinula globosa Duff. var. *stricta* R. Jones.

Most of the Southern Rhodesian material collected by the Survey is crowded with this small Ostracod. It is to be found also in Molyneux's duplicate specimens from N'koka's Kraal, and in the specimen of black shale containing *Palaeanodonta wadei* from Tanganyika (Tanganyika Survey, Locality S. 929).

It is recorded also by Leriche (5) and Veatch (8, p. 136) from Middle Beaufort Beds in the Stanleyville area in the Belgian Congo. A careful search among specimens in the South African Museum, Cape Town, failed to find any trace of this ostracod in material from South African Beaufort fossiliferous beds.

Pisces.

The material consists of isolated scales, a few fragments of bone and one fin-spine 2½ inches long. One scale approximates very closely to a figure given by Egerton in 1856, in the *Transactions of the Geological Society of London*, ser. 2, vol. vii, pl. xxviii, fig. 40, and named by him *Palaeoniscus sculptus.* This came from Lower Beaufort Beds at Styl Krantz in the Union of South Africa. Though there can be little doubt that these scales belong to the same species of fish, it is very doubtful if the species should be referred to the genus *Palaeoniscus.* This was pointed out by Smith Woodward in his *Catalogue of Fossil Fishes,* though he did not attempt to classify Egerton's species further. Beyond this, and beyond the fact that none of the scales agrees with *Acrolepis molyneuxi* S. Woodward or with any species recently described from the Karroo rocks of the Belgian Congo, Tanganyika, or Nyasaland, it is not possible to go, until more material is available.

Figures are given of—

Scale of *Palaeoniscus sculptus* Egerton, Fig. 4, Pl. X.
Fin-spine (sp. indet.), Fig. 5, Pl. X.

Correlation.

Fossils have previously been recorded from the Madumabisa Shales and Upper Matabola Beds by Molyneux (7) and Maufe (6). This new locality, at Madziwadzido, is on the same lithological group and all three localities are sufficiently close together for lithological correlation to be reliable. The faunal list from the Southern Rhodesian Upper Matabola Beds is set out below, and it can now be examined to see what fresh evidence is available for correlation with other Southern African faunas.

Faunal list of Upper Matabola Beds.

**Palaeomutela sp.* (*rhomboidalis* group).
**Palaeomutela neglecta* (Jones).
**Archanodon subcastor* (Amal.). Probably synonymous with *Palaeanodonta subcastor* (Amal.).
Palaeomutela rectodonta Amal.
Palaeanodonta wadei Cox.
P. parallela (Amal.).
P. castor (Eichw.).
P. subcastor (Amal.).
Darwinula globosa Duff. var. *stricta* R. Jones.
*Estheria ?
**Acrolepis Molyneuxi* S. Woodward.
Scale of *Palaeoniscus sculptus* Egerton.

Species marked * have been previously recorded from Southern Rhodesia.

Precise correlation by means of non-marine Lamellibranchs requires a detailed statistical analysis of large numbers of specimens. A broad correlation can, however, be made out from the general aspect of such a fauna as that listed above.

In 1936 Dixey (3) published a provisional correlation table of the Karroo system in Central Africa and Madagascar in which the Madumabisa Shales are correlated with the Upper Matabola Beds and assigned to the Lower Beaufort. The equivalence of the Upper Matabola Beds with some part of the Beaufort series was also discussed by du Toit (4, p. 254).

The fauna from Madziwadzido bears strong points of resemblance to the faunas described by Cox (1) (2), in 1932 and 1936 from Karroo rocks in Tanganyika, and it is by comparison with the Tanganyika succession that it can best be correlated with the established succession in South Africa.

The species *Palaeomutela neglecta* (Jones) and *P. rectodonta* (Amal.) occur in the Tanganyika series. There the beds in which they are found

are overlain by a bed containing vertebrate forms which have been referred by Haughton to a Middle Lower Beaufort horizon. *Palaeomutela rectodonta* (Amal.) also occurs in Lower Beaufort beds in the Union of South Africa. Furthermore, Cox remarks (1, p. 623) that the genera *Palaeanodonta* and *Palaeomutela* have never been found in South Africa in beds of any other age than Lower Beaufort.

In 1936 Cox described another fauna from Tanganyika which contained many species of *Palaeanodonta*. Four species from Madziwadzido agree very closely with forms in this Tanganyika fauna. They are *Palaeanodonta wadei* Cox, *P. parallela* (Amal.), *P. castor* (Eichw.), *P. subcastor* (Amal.). This fauna Cox again referred to a Lower Beaufort horizon, with the reservation that it might possibly represent the very top of the Ecca. There are several specimens from this fauna supplied by the Tanganyika Survey in the Collection of the National Museum of Southern Rhodesia in Bulawayo and comparison has been made with this material. It was found that the ostracod *Darwinula globosa* Duff var. *stricta* R. Jones occurred in a specimen from Tanganyika, which also contained *Palaeanodonta wadei* Cox. This ostracod does not appear to have been recorded from Tanganyika at the time when the fauna was described. It is known from the Belgian Congo from beds which Veatch (8) places in the Upper Middle Beaufort.

Fragmentary though the fish remains are, they provide further evidence for correlation. The solitary scale which seems identical with Egerton's *Palaeoniscus sculptus* can only be matched with his solitary scale from Styl Krantz in the Union of South Africa. This locality is on Lower Beaufort beds.

The evidence from non-marine Lamellibranchs, Fish, and Ostracods from Madziwadzido all points, therefore, to a Lower Beaufort age for this new fossiliferous locality and gives further support to the correlation of the Upper Matabola Beds of Southern Rhodesia with the Lower Beaufort of the Union of South Africa, the correlation being in part direct, and in part through comparison with the succession in Tanganyika.

More exact correlation cannot be expected owing to the phasal character of the fauna, and to the fact that "species" of non-marine Lamellibranchs defined by means of so few individuals may range through a very long period in time.

Acknowledgments.

I am much indebted to Mr. A. M. Macgregor of the Southern Rhodesia Geological Survey, who collected the material, for sending this fauna to me; to Major Lightfoot, M.C., M.A., the Director of the Southern Rhodesia Geological Survey, for permission to publish the results; to Dr. Arnold, Director of the National Museum of Southern Rhodesia; and Dr. Barnard,

Director of the South African Museum in Cape Town, where the work was carried out, and to Mr. John Adams, A.I.B.P., A.R.P.S., for taking the photographs which illustrate the paper.

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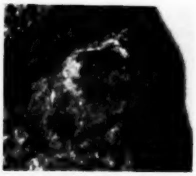
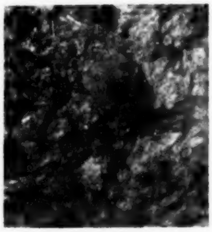


Fig. 1.



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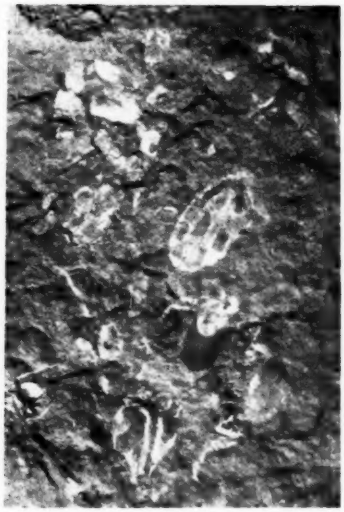

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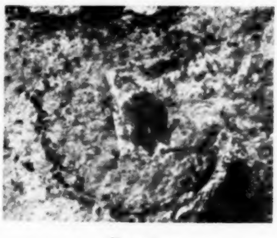

Fig. 4.

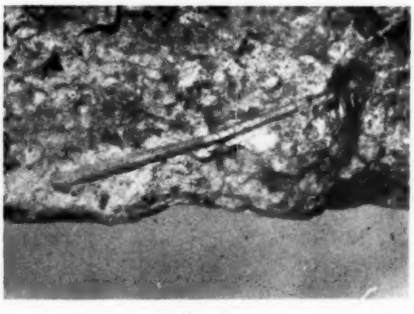

Fig. 5.

Fossils from the Upper Matabola Beds of Madziwadzido, Sesame River, Sebungwe District, Southern Rhodesia. (All Geological Survey specimens.) Fig. 1. *Palaeomutela rectodonta* Amal. × 2. Fig. 2. *Palaeanodonta wadei* Cox. × 2. Fig. 3. *Palaeanodonta subcastor* (Amal.). × 2. Fig. 4. *Palaeoniscus sculptus* Egerton, nat. size. Fig. 5. Fin-spine. Sp. indet. nat. size.

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SKELETAL MATURATION, SOMATOMETRIC INDICES AND BLOOD HÆMOGLOBIN LEVEL IN THE DETECTION OF HUMAN MALNUTRITION: A STATISTICAL ANALYSIS.

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(Read June 16, 1943.)

The following analysis is part of a study by the Cape Nutrition Survey of the criteria by which human malnutrition can be recognised. The objectives and methods of the survey have been published (Brock and Latsky, 1942).

The chief problem of nutritional surveys is to find methods whereby a large group of individuals can be quickly classified into "probably normal" and "probably malnourished" groups. The Public Health Department of the Union of South Africa carried out in ?1938 a preliminary survey of European schoolboys throughout the Union. In brief, the work was carried out by School Medical Officers throughout the four Provinces of the Union, who examined, weighed, and measured school children after having met to agree on the standards to be adopted. After examination each child was put in one of the four conventional groups of the Dunfermline scale (Bigwood, 1939): 1, Excellent; 2, Good; 3, Slightly subnormal; 4, Bad. 58,165 European boys were examined and classified in this way. Classes 1 and 2 were regarded as of satisfactory nutrition, and classes 3 and 4 were regarded as malnourished. The percentage figures for the Union were: Nutrition satisfactory, 59·7 per cent.; malnourished, 40·3 per cent.

The question immediately arose as to how much reliance could be placed upon the conclusion that 40·3 per cent. of these boys were malnourished. It is quite clear that the figures cannot be regarded as accurate because there is no generally accepted standard of normality. Although all examiners would be agreed on the recognition of the differences between classes 1 and 4 of the Dunfermline scale, there would be no agreement as to just where the border lay between groups 2 and 3. Jones (1937) has discussed this matter fully and shown that no two examiners will agree in this matter.

The Cape Nutrition Survey set out to study methods of making nutri-

tional assessment more exact. In a very detailed study approximately 1000 children were divided into three groups: (1) Diseased, (2) Malnourished, and (3) Normal. The methods of this classification have been set out elsewhere (Brock and Latsky, 1942). The Dunfermline scale was its basis.

In the present study the distribution of the results of certain objective indices are compared in the two groups Normal and Malnourished to determine whether they can be used to distinguish between Normal and Malnourished children either in groups or as individuals. The results have been submitted to statistical analysis. The indices studied were the following:—

1. *Flory's Skeletal Maturation Index.*—According to Flory (1936), epiphyseal development in the wrist can be classified so as to give the skeletal age of the child. When osseous development of the child is retarded the skeletal age will be less than the actual age of the child. Flory's standards were established from among 5000 X-rays taken of the wrists of children attending the Chicago (U.S.A.) Laboratory Schools during the years 1932 to 1934. In some cases continuous records were obtained of the same children from five to seventeen years of age. Apparently no selection was made on the basis of nutritional status and no information is given as to their socio-economic status. The X-rays were all taken within one month of the child's birthday and in most cases within one week. Finally one hundred X-rays, excellent in photographic quality, were selected at each age for each sex. Typical X-rays for each age in each sex are reproduced in Flory's monograph. Flory claims that the standards are sufficiently different in degree of ossification that an inexperienced student can be taught the major distinguishing marks in a few minutes. An attempt was made in the present Survey to see whether skeletal development would be retarded to a significant degree in the malnourished children as compared with the normal children in relation to Flory's standards. An X-ray of the right wrist had been taken in each child under standard conditions. From these X-rays 420 were selected (all Coloured), of which 210 came from the malnounrished group and 210 from the normal group. The same number in each group came from each six-month age-period from 9 to 15 years inclusive, so that the average age of the children in each group of 210 was identical, *i.e.* 11·8 years. The X-rays were then mixed up so that there could be no bias in the assessment of the skeletal age. The assessments were all made by one of us (J. M. L.), the skeletal age of the child being determined from Flory's standards for each sex. In the following discussion the term skeletal advancement means that the child's skeletal age (Flory) was greater than its age in years. The method is not regarded as very accurate, since it is not always easy to determine into which six-month group the X-rays should be placed; *e.g.*

whether 11·0 years or 11·5 years. The fact, however, that the assessment was made entirely without bias and on a large series of cases probably makes the results of some value.

2. *Wetzel's Developmental Age* is a somatometric index because it is derived from measurement of height and weight. Wetzel (1941) has devised a grid based on measurements of height and weight in relation to age. He claims that his seven channels represent a range of physique from the obese to the very slender type. Healthy developmental progress continues in an established channel as though this were a preferred path. Channel-wise progress indicates development with preservation of given physique; cross-channel progress is accompanied by change in physique. Developmental level is measured on the grid by means of the isodevelopmental level lines expressed in arbitrary units. The auxodromes are a series of curves which measure relative age advancement or retardation. The centre auxodrome expresses the developmental level reached by 67 per cent. of the children and is the standard of reference by which advancement or retardation of a given child is measured. The developmental age of the child is read by tracing its developmental level on the grid across to 67 per cent. auxodrome and this is expressed as developmental advancement or retardation in relation to the actual age of the child.

The grid is stated to have been constructed from more than 25,000 paired sets of measurements on 4000 children in the United States of America, and to have given a gross agreement with clinical appraisals by school physicians of 78·5 per cent. Details of the calculations are not given so that the validity of the author's claims cannot be examined. The racial composition of the children is not given, so that no estimate can be formed of the applicability of the grid as a measure of development of South African children.

3. *The Blood Hæmoglobin.*—The blood hæmoglobin shows a very wide range of "normality" at different ages and in different parts of the world. Certain deficiency states, notably iron deficiency, are always associated with a lowered hæmoglobin. Even without the effects of parasitic infestation it is usually assumed that malnutrition gives rise to a lowered hæmoglobin level, but some workers have commented upon the high levels of hæmoglobin sometimes encountered in badly malnourished cases. Davidson *et al.* (1942) recently claimed that there has been in the last few years in Scotland a fall in average hæmoglobin levels in children without obvious deterioration in state of nutrition. This fall they attributed to deterioration in diet as a result of the war.

The hæmoglobin figures referred to in the present discussion were read on capillary blood by means of a Sicca hæmometer calibrated at 100 per cent. for 13·8 grammes of hæomglobin per cent. The accuracy of the

reading was found to be ± 1 per cent. Taking the hæmoglobin figures of all children in the Normal and Malnourished Groups on whom the hæmoglobin was recorded (Brock and Latsky, 1942) the mean figures for the two groups were 104·5 per cent. and 100 per cent., representing 14·5 and 15·8 grammes of hæmoglobin per 100 c.c. of blood respectively. This difference in the means was found to be statistically significant, suggesting that malnutrition is reflected in a lowered hæmoglobin level. The overlap between the two groups was, however, so great that the hæmoglobin level could ovbiously not be used to detect malnourished children.

The Subjects.—The following statistical analysis is concerned mainly with a comparison of two groups of children from among the 1000 examined by the Cape Nutrition Survey. They are all Cape Coloured children and consist of 210 from the Normal group and 210 from the Malnourished group selected at random by age groups as described under the heading "Flory's skeletal maturation index" above. In paragraph *A*. 4, however, a comparison is made between the 210 Normal Cape Coloured children and 440 Flory U.S.A. girls between the ages of 9 and 15. These girls were a group selected for special study by Flory because they had consecutive X-rays over a long period of years.

Statistical Analysis.—We assume that the basic division of the children by the Cape Nutrition Survey into Normal and Malnourished groups is valid and that the 210 Normals constitute a random sample of the parent Normal population. The normality of the nutritional state of a child cannot be detected, except in extreme cases, by single measurements of Hb level, skeletal and developmental ages. On the other hand, in large groups, such measurements disclose statistically significant differences between the normals and malnourished. These differences will now be discussed, the references being to the tables in the Appendix.

Definitions.—The terms *statistic* and *parameter* will be used * to denote any statistical index such as a mean, variance, distribution, etc. belonging to a group and to the parent population respectively.

A. Skeletal and Developmental Advancement.

The skeletal and developmental advancements tend to zero at both ends of the chronological age range and some of the lack of homogeneity in the various statistics can be ascribed to this cause.

A. 1.—At all ages and for both males and females the mean skeletal and developmental advancements of the normals exceed those of the malnourished. Although few of the differences, age by age, are significant yet the aggregate of the probabilities is so. ($P < \cdot 0001$.)

* R. A. Fisher: *Statistical Methods for Research Workers*, 7th ed., 1938, pp. 7–8.

A. 2.—The mean skeletal and developmental advancements of all the normals exceed those of all the malnourished by ·92 years and ·61 years respectively, being the same for both sexes. (P<·001.) Tables A 3, C 3.

A. 3.—Neither the skeletal nor the developmental advancements nor their variances show any decided trend with age. The correlation coefficients between age and developmental advancement are $r = -·10$; P>·10 for normal males and $r = -·18$; P>·05 for malnourished males. There is therefore a hint here that retardation has been progressive with age in many instances in the malnourished group. Tables A, C.

A. 4.—Age by age the skeletal advancement of the 210 Normal S.A. Coloured children exceeds that of the Flory 440 U.S.A. girls, nearly all the differences being significant. (P<·001.)

The mean excess of the whole group, ·52 years, is significant.

These Flory girls were, in the aggregate, skeletally advanced with respect to the Flory scale and there was an increase with age.

A. 5.—The mean skeletal and developmental advancements of the 210 Normal children over the Flory and Wetzel scales were respectively ·70 and ·52 years, being the same for both sexes. (P<·001.)

B. Comparison of Skeletal and Developmental Ages.

B. 1.—Both for normals and malnourished there is a high correlation coefficient between the skeletal and developmental ages when the effects of chronological age have been partially eliminated. All these coefficients are significant and no essential differences are disclosed in the values for normal and malnourished nor for age nor sex. Tables D, E.

B. 2.—In the normal group, at most ages, the skeletal age exceeds the developmental and although the individual differences, age by age, are not significant yet the aggregate probabilities are so. (P<·01.) Table D.

On the other hand, in the malnourished group there is a hint that the developmental age exceeds the skeletal. (P<·04.) Table E.

This difference is further illustrated by:—

Normals:	In 121	cases	skeletal	>	developmental.
	,, 7	,,	,,	=	,,
	,, 82	,,	,,	<	,,
Malnourished:	,, 82	,,	,,	>	,,
	,, 6	,,	,,	=	,,
	,, 122	,,	,,	<	,,

The high correlation noted in B. 1 and the fact that expensive apparatus, great skill, experience and time are required to ascertain the skeletal age, whereas the developmental age is cheaply and readily determined, suggest

that, although the skeletal mean differences between normal and malnourished are greater than the developmental, the latter may be used in place of the former in preliminary studies on large groups.*

C. Hæmoglobin.

C. 1.—For both sexes, except round about age 13 years, the mean Hb levels of the normals exceed those of the malnourished at each age.

Although only two of these differences are significant yet the aggregate probability is so. ($P<{\cdot}001$.) Table E.

C. 2.—The age by age probabilities of the Hb differences between normal and malnourished are not as significant, on the whole, as those for skeletal or developmental differences.

C. 3.—There is a significant increase of mean Hb with the age of the sub-group except about age 13, at which there is a fall tending to significance.

These age effects do not appear to have any connection with nutrition.

C. 4.—There is no significant correlation between Hb and skeletal advancement:

$$r={\cdot}09;\quad P>{\cdot}10.$$

D. Wetzel Channels.

According to Wetzel, "normal progress is along a channel of given body type and at a rate specific for the subject". Unhealthy or malnourished progress is marked by a tendency to change channel towards B. 4.

Owing to the small numbers involved the conclusions drawn are doubtful. Nevertheless they tend to confirm Wetzel's statements and also indicate new uses for his grid in studies on malnutrition in groups.

The Hb data have not been corrected for the age effects mentioned in C. 3 above.

In interpreting the following results it is necessary to bear in mind that a healthy well-nourished child may be retarded as compared with the mean parameter for his own channel. Also a retardment or advancement in the skeletal or developmental age of a child must persist for some time and that, in consequence, a child's nutritional status and his somatometric status at particular instants may not be closely correlated.

D. 1.—The mean Hb, mean skeletal and mean developmental advancements decrease in passing from channel A. 4 to channel B. 4 for both normal and malnourished groups (except channel B. 3). Table F.

Although in some instances the differences between channels are not significant yet they give an impression of being so in the aggregate, *e.g.* for Hb of normals the probabilities of the successive decreases being exceeded in random sampling are ·42, ·0001, ·0001, ·0001, ·14 respectively.

* One essential difference must be pointed out. The skeletal age never decreases, whilst the developmental may.

The channel fall in developmental advancement might be ascribed to an inadequacy of the Wetzel grid for South African Coloureds, but this would not explain the channel falls in Hb levels and skeletal advancements.

If the fall is a real phenomenon, it is necessary, when comparing the statistics of different groups, to eliminate this effect as well as possible second-order effects due to age.

D. 2.—In every instance the mean Hb in malnourished children is greater than that for normal children channel by channel, whilst the reverse is generally the case for the mean skeletal and developmental advancements.

The explanation seems to be that the Hb is but little effected by causes producing a channel-shift in the malnourished and this tends to be confirmed by the facts noted in C. 2 above.

Conclusions.

Although, owing to the very large overlap between the distributions of Hb level, skeletal and developmental advancements, single measurements of these indices have only a limited value in the detection of malnutrition in the individual, yet in large groups there are statistically significant differences in the statistics. These differences may be used in the detection of malnourishment in large groups if due precautions are taken in interpreting the results. The parameters belonging to a genetically stable normal population with which the statistics of a group are to be compared are:—

A mean and variances of the whole; a definite per cent. distribution of its members amongst the various Wetzel channels; a mean and variance for the subgroups in each channel.

If, after any possible secondary age effects have been eliminated, the statistics for a large group are significantly in defect of the corresponding parameters the group probably contains a large per cent. of children who are now, or have been in the recent past, malnourished or diseased. It is therefore desirable to determine the above parameters, especially those relating to developmental advancements, the experiments being designed on such a scale and in such a manner that secondary effects due to age can be eliminated as well as those possibly due to genetic, climatic, and geographical conditions.

The parameters have not been determined.

Certain nutritional principles may be deduced from the foregoing analysis. Provided that the basic division of the children by the Cape Nutrition Survey into Normal and Malnourished groups is valid.

1. Both skeletal maturation and Wetzel's developmental age are retarded by malnutrition.

2. The hæmoglobin level is adversely affected by malnutrition, although

to a less extent than are skeletal maturation and development. This conclusion is in keeping with the findings of many others.

3. All three indices are affected also by factors which are not concerned with the diet.

4. These non-dietary factors exert so much influence on the three indices that the indices are only of limited value in the detection of malnutrition in individual children.

5. The high correlation (B. 1) between the skeletal and developmental ages is very surprising.

Skeletal maturation is generally assumed to be under the predominant control of the endocrine glands; hence the considerable sex differences and correlation of skeletal maturation with onset of puberty (Flory, 1936). It is known that injections of male hormone may accelerate skeletal maturation. Thyroid deficiency in infants (cretinism) retards skeletal maturation. Todd (1938) concluded that there was no difference in the ossification of the carpal centres between poverty-stricken infants and a supervised group.

Developmental age, on the other hand, is derived from bone growth and tissue mass. Both of these are generally assumed to be influenced to a considerable extent by malnutrition, although it is probable that skeletal (stature) growth at least may proceed rapidly at puberty even in the presence of considerable malnutrition.

The high correlation found in this study between skeletal and developmental ages, together with the finding that both are influenced by malnutrition, suggests that dietary influences may exert greater influence than had been assumed over the process of skeletal maturation.

6. Since the skeletal advancement exceeds the developmental advancement in normal children but not in malnourished children, this may mean that skeletal maturation is more effected by malnutrition than is skeletal and tissue growth. This conclusion is surprising.

7. So far the figures have not been examined for correlation between skeletal maturation and skeletal growth (as measured by stature) in the normal and malnourished groups. If skeletal advancement (maturation) exceeds skeletal growth (stature) in normal children but not in malnourished children then conclusion 6 would be strengthened.

8. The fact that the 210 Normal Cape Coloured children are skeletally and developmentally in advance of Flory's and Wetzel's scales for American children may mean either

(*a*) that Cape Coloured children tend racially to more rapid maturation and development than do American children; or

(*b*) that Normal Cape Coloured children are a more strictly selected group and therefore nutritionally superior to the larger less strictly selected American children.

9. Many other interesting conclusions could be discussed but are at present too conjectural. It must be emphasised that even the above tentative conclusions all depend upon the assumption that the basic division of the children by the Cape Nutrition Survey into Normal and Malnourished groups is valid, and that the 210 normals constitute a random sample of the parent population.

Acknowledgment.—The work of the Cape Nutrition Survey was supported financially by the Union Department of Health.

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APPENDIX.

NOTATION.

M = a mean in years or in per cent.

σ = standard deviation in years or per cent.

"t" = students "t."

P = approximate probability that "t" or X^2 will be exceeded in random sampling.

$P < \cdot 01$ will be regarded as statistically significant.

$r\ i, g$ = coefficient of correlation between the sets with means Mi and Mg.

N = number of children in a group.

n = number of degrees of freedom.

X^2 generally refers to the set of probabilities and measures the chance that although each may not be significant the aggregate may be so. In other cases it measures differences in the distribution of two groups in a contingency table.

[TABLES.

TABLES A.

SKELETAL ADVANCEMENTS OF 210 NORMAL AND 210 MALNOURISHED COLOURED.

121 *Males.* 89 *Females.*

Chron. Age		9	10	11	12	13	14	15	Totals.	9	10	11	12	13	14	15	Totals.
N.		19	19	18	18	16	16	15	121	11	11	12	12	14	14	15	89
A. 1	Mean Age, M_1	8·96	9·94	10·88	11·91	12·95	14·00	14·96		9·08	10·01	11·03	11·92	13·1	13·97	14·75	
	Mean Sk. Age, M_2	9·63	10·52	11·64	12·61	13·41	15·12	15·37		9·45	10·82	11·25	13·33	13·82	14·64	15·47	
Normal	Mean Sk. Adv., M_3	·67	·59	·76	·71	·46	1·12	·41	+ ·68	·37	·81	·22	1·42	·72	·67	·79	+ ·72
	σ_3^2	1·10	2·19	1·51	1·32	1·90	1·42	·33		·77	1·17	1·07	·66	·44	·12	1·16	
	t_3	2·79	1·74	2·64	2·62	1·33	3·76	2·75		1·4	2·49	·74	6·4	4·09	7·0	2·84	
	P_3	·005	·05	·01	·01	·10	·004	·008		·10	·02	·23	·001	·001	·001	·006	$X^2 = 127·4$; $P < ·001$
A. 2.	Mean Age, M_4	9·11	9·93	10·96	11·93	12·98	14·02	14·94		9	9·88	10·99	12·07	12·99	13·86	14·87	
Malnourished	Mean Sk. Age, M_5	8·61	9·90	10·28	11·94	12·82	13·91	15·08		8·5	10·0	10·21	11·92	12·97	14·00	14·66	
	Mean Sk. Adv., M_6	−0·5	−0·03	−0·68	+ ·01	−0·16	−0·11	+0·14	−0·24	−0·5	+0·12	−0·78	−0·15	−0·02	+0·14	−0·21	−0·20
	σ_6^2	1·24	1·15	2·74	1·25	1·74	·85	1·38		·80	3·02	1·56	·96	2·00	·98	1·52	
	t_6	−1·87	− ·22	−1·74	+·039	− ·49	− ·48	+ ·49		−1·86	+ ·23	−2·16	− ·53	− ·53	+ ·53	− ·66	
	P_6	·96	·65	·95	·47	·68	·68	·31		·95	·41	·98	·70	·70	·30	·74	$X^2 = 44·16$; $P = ·02$
A. 3.	M_3–M_6	1·17	·61	1·45	·70	·63	1·23	·55	+ ·92	·87	·69	1·00	1·57	·74	·53	1·00	+ ·92
Normal minus	$t_{3,6}$	3·26	1·44	2·97	1·80	1·32	3·27	1·63		2·70	·80	2·14	4·50	2·10	2·00	2·36	
Maln.	$P_{3,6}$	·0006	·075	·002	·036	·093	·0006	·052		·003	·21	·016	·0001	·018	·023	·009	$X^2 = 129·7$; $P < ·001$

TABLES B.

COMPARISON OF SKELETAL STATISTICS OF 440 NORMAL U.S.A. GIRLS (FLOREY) AND 210 NORMAL S.A. COLOUREDS.

AGE		9	10	11	12	13	14	15	
B. 1.	N	55	65	64	59	66	65	66	
FLOREY	M_7	−·046	−·08	0	·246	·38	·40	·303	
	σ_7^2	1·02	·77	·84	1·01	·93	·90	·88	
B. 2.	N	30	30	30	30	30	30	30	
NORMAL COLOURED	M_8	·56	·67	·54	·99	·58	·91	·60	
	σ_8^2	·85	1·80	1·37	1·18	1·20	·50	·76	
B. 3.	M_8-M_7	·61	·75	·54	·74	·20	·57	·29	Mean = + ·52
NORMAL MINUS FLOREY	$t_{7,8}$	2·83	3·26	2·74	3·2	·90	2·64	1·30	
	$P_{7,8}$	·0023	·0006	·0031	·0007	·184	·004	·097	$X^2 = 72{\cdot}4$; $P < {\cdot}001$
B. 4. MALNOURISHED COLOURED	σ^2	1·12	1·76	2·19	·97	1·8	·90	1·44	

TABLES C.

DEVELOPMENTAL ADVANCEMENTS OF 210 NORMAL AND 210 MALNOURISHED COLOUREDS.

121 *Males.* 89 *Females.*

Age		9	10	11	12	13	14	15	Totals.	9	10	11	12	13	14	15	Totals.
C. 1.	Mean dev., M_9	9·44	10·15	11·42	12·45	13·28	14·67	15·5		9·15	10·61	11·61	12·61	13·52	14·8	15·37	
Normals	Mean dev. adv., M_{10}	·48	·22	·54	·54	·33	·68	·54	+·48	·07	·60	·58	·69	·42	·84	·62	+·55
	σ_{10}^2	·78	1·04	1·24	1·24	·59	·42	·29	1·03	1·01	·96	·99	·34	·38	·47	·82	1·03
	t_{10}	2·36	·94	2·06	2·06	1·73	4·19	3·85		·22	1·93	2·02	4·0	2·54	4·6	2·66	
	P_{10}	·018	·17	·025	·025	·05	·001	·003		·42	·035	·038	·003	·015	·002	·01	$X^2 = 114$; $P < ·0001$
C. 2.	Mean dev., M_{11}	9·02	9·81	10·24	11·96	12·80	13·81	15·27		8·7	10·13	10·68	11·88	13·17	14·13	14·67	
Malnourished	Mean dev. adv., M_{12}	−·08	1·12	−·71	+·03	−·20	−·21	+·33	−·13	−·34	+·25	−·31	−·19	+·18	+·26	−·21	−·04
	σ_{12}^2	·46	·73	2·18	·83	1·81	1·59	1·07	1·27	·33	1·00	·94	1·25	1·88	·65	1·71	1·06
	P_{12}	·70	·72	·97	·45	·74	·59	·12		·96	·21	·85	·71	·32	·13	·72	$X^2 = 32·6$; $P = ·75$
Normal minus Malnourished	$M_{10}-M_{12}$	·57	·34	1·25	·51	·53	·89	·21	+·61	·41	·35	·88	·88	·24	·58	·83	·59
	$t_{10, 12}$	2·24	1·11	2·87	1·15	1·36	2·52	·56		1·14	·85	2·19	2·42	·59	2·06	2·02	
	$P_{10, 12}$	·012	·13	·005	·12	·09	·007	·30		·14	·20	·025	·01	·30	·025	·025	$X^2 = 85·84$; $P < ·0001$

TABLES D.

COMPARISONS OF SKELETAL AND DEVELOPMENTAL AGES.

121 *Males.* 89 *Females.*

Age		9	10	11	12	13	14	15	Totals.	9	10	11	12	13	14	15	Totals.
D. I.	Skl. M_{13}	9·63	10·52	11·64	12·61	13·41	15·12	15·37		9·46	10·82	11·25	13·33	13·82	14·64	15·47	
Normals	σ_{13}^2	1·13	2·01	1·43	1·02	1·94	1·11	·49		·62	1·16	·84	·70	·60	·21	·87	
	Dev. M_{14}	9·44	10·15	11·42	12·45	13·28	14·67	15·50		9·15	10·61	11·61	12·61	13·52	14·81	15·37	
	σ_{14}^2	·73	1·49	1·27	·82	1·09	·64	·54		·90	·74	·76	·45	·37	·83	1·19	
	$M_{13}-M_{14}=M_{15}$	·19	·37	·22	·16	·13	·45	−·13	+·2	·30	·21	−·36	·73	·30	−·16	·10	+·16
	σ_{15}^2	·28	·34	·34	·38	·36	·35	·27		·55	·38	·32	·30	·28	·41	·39	
	t_{15}	1·38	2·35	1·59	1·09	·87	3·03	·96		1·34	1·13	2·21	4·6	2·12	·93	·62	
	P_{15}	·10	·02	·08	·15	·20	·005	·82		·10	·14	·98	·002	·025	·82	·38	$X^2=66{\cdot}05$; $P=\cdot003$
	$r_{13,14}$	·68	·91	·88	·79	·91	·83	·73		·65	·81	·80	·76	·73	·76	·82	

TABLES D.

COMPARISONS OF SKELETAL AND DEVELOPMENTAL AGES.

121 *Males.* 89 *Females.*

	Age	9	10	11	12	13	14	15	Totals.	9	10	11	12	13	14	15	Totals.
D. 2.	Skl. M_{16}	8·61	9·90	10·28	11·70	12·81	13·91	15·10		8·50	10	10·21	11·92	12·96	14	14·67	
MALNOURISHED	σ_{16}^2	1·21	1·13	2·77	1·20	1·63	·71	1·44		1·00	2·85	1·43	1·04	1·52	1·04	2·23	
	Dev. M_{17}	9·02	9·81	10·24	11·96	12·78	13·81	15·27		8·66	10·13	10·68	11·88	13·17	14·13	14·67	
	σ_{17}^2	·46	·65	2·09	·87	1·66	1·35	1·62		·41	1·18	·91	1·25	1·40	·66	2·63	
	$M_{16}-M_{17}=M_{18}$	−·42	+·08	+·03	−·27	+·04	+·10	−·17	+·09	−·16	−·13	−·48	+·04	−·21	−·13	0	−·19
	σ_{18}^2	·66	·36	·39	·48	·33	·42	·37		·54	1·14	·35	·54	·20	·43	·18	
	t_{18}	2·25	·61	·22	·86	·26	·62	1·10		·74	·41	2·8	·19	1·76	·74	0	
	P_{18}	·88	·28	·42	·80	·40	·26	·85		·76	·65	·98	·42	·95	·77	·50	$X^2=15·02$; $P=·96$
	$r_{16, 17}$	·68	·83	·93	·78	·92	·84	·88		·68	·80	·87	·80	·94	·76	·96	

TABLE E.

COMPARISON OF HÆMOGLOBIN OF 210 NORMALS AND 210 MALNOURISHED.

AGE		9	10	11	12	13	14	15	Totals.	9	10	11	12	13	14	15	Totals.
E. 1.	M_{19}	0	1·47	4·22	2·56	−·19	7·5	6·0		·46	1·36	4·25	3·36	1·14	4	6·07	
NORMAL	σ_{19}^2	33·9	33·1	27·7	40·5	47·5	27·8	19		43·1	38·9	13·6	20·5	36·3	32·3	42·9	
E. 2. MALNOURISHED	M_{20}	−1·1	·47	−1·39	−·39	2·06	3·38	4·80		−·73	·55	2·25	1·42	·36	4·43	1·2	
	σ_{20}^2	37·5	37·5	22	14·25	16·6	34·9	11·9		11·82	7·47	9·66	20·08	35·48	10·94	11·17	
E. 3.	$M_{19}-M_{20}=M_{21}$	1·1	1·0	5·61	2·95	−2·25	4·12	1·2	2 per cent.	1·19	·81	2·0	1·94	·78	−·43	4·87	1·66 per cent.
NORMAL MINUS MALNOURISHED	t_{21}	·56	·52	3·45	1·68	−1·12	2·14	·84		·53	·40	1·44	1·05	·34	−·24	2·56	
	P_{21}	·30	·30	·0003	·047	·87	0·16	·20		·30	·35	·07	·15	·37	·59	·005	$X^2=64·20$; $P=·0002$

Means measured from a zero of 100 per cent. Hb.

TABLE F.

STATISTICS RELATING TO WETZEL CHANNEL DISTRIBUTION OF 210 COLOURED NORMALS AND 210 COLOURED MALNOURISHED.

	A_4.	A_3.	A_2.	A_1.	M.	B_1.	B_2.	B_3.	B_4.
M_1			107·5 ..	107·2 ..	104·1 109·6	100·7 102·8	97·2 101·5	92·8 99·0	 96·3
M_2			·95	·91	·87 1·47	·49 – ·21	·06 – ·26	·48 – ·32	 – ·47
M_3			·81 ..	·79 ..	·59 ·90	·31 ·05	0 – ·04	·04 – ·38	 – ·38
σ_1^2			34·8 ..	21·7 ..	14·0 12·7	24·1 17·6	16·2 10·9	22·7 13·9	 28·3
σ_2^2			·79 ..	·98 ..	·88 1·05	·85 1·01	1·46 1·37	·51 1·29	 3·03
σ_3^2			·91 ..	·76 ..	·52 1·03	·81 ·86	·98 1·02	1·03 1·27	 1·73
N	1 ..	3 ..	13 ..	44 1	62 11	52 50	30 69	5 51	 28

Normals above.
Malnourished below.
Suffix 1 refers to Hb.
Suffix 2 refers to Skeletal adv.
Suffix 3 refers to Developmental adv.

G. Contingency Tables.

(210 Normal, 210 Malnourished Coloured.)

Normal Above, Malnourished Below, Developmental on Left, Skeletal on Right.

Chron. Age	A_4.	A_3.	A_2.	A_1.	M.	B_1.	B_2.	B_3.	B_4.
9			2	7	5	8 11	7 12	1 3	 4
10	1	1	2	1 1	7 1	15 7	3 7	 7	 7
11			2	9	11 1	5 4	3 15	 4	 6
12			2	6	6 1	7 7	9 13	 6	 3
13			2	8	8 2	5 6	4 8	3 12	 2
14		2	2	6	10 5	7 5	3 7	 9	 4
15			1	7	15 1	5 11	1 8	1 7	 3

G. 1.

Age and Channel.

Dev. adv.	A_4.	A_3.	A_2.	A_1.	M.	B_1.	B_2.	B_3.	B_4.	Skl. adv.
4		1 1								
3		1 1	1	1 3	1 3 1 2	1				
2			1 5	9 7	3 11 1 3	3 3 2 1	3 4 1	 2 2	 1 3	
1	1 1	1 1	5 2	16 19	29 23 5 3	18 24 13 14	8 9 7 13	1 3 5 10	 3 4	
0			5 6	16 14	25 24 3 3	24 18 22 15	14 13 46 35	3 2 23 20	 15 11	
-1			1	2 1	4 1 1	4 4 12 16	6 4 7 10	1 16 13	 5 4	
-2						3 2 1 4	1 1 3 7	 3 4	 2 3	
-3							1 1 2	 1 1	 1 1	
-4							1 1 1	 1 1	 1 1	
-5									1	

G. 2.

Developmental and Skeletal Advancement.

TABLE G. 3.

Hb.	A_4.	A_3.	A_2.	A_1.	M.	B_1.	B_2.	B_3.	B_4.	
85						1	2		 1	3 1
90			1	1		2 1	2	3 3	 6	9 10
95					2	7 3	8 8	 7	 8	17 26
100				5 1	15	24 23	16 33	2 31	 10	62 98
105			6	14	37 2	15 14	2 26	 9	 3	73 54
110	1	1	4	22	7 8	2 9	 2	 1		35 20
115		2	2	2	1 1	1				8 1
Totals	1	3	13	14 1	62 11	52 50	29 69	5 51	 28	210 210

Hb and Channel.

THE WARM SPRINGS AT LOUBAD, NEAR NYLSTROOM, TRANSVAAL.

By Leslie E. Kent.

(With three Text-figures.)

(*Published by permission of the Honourable the Minister of Mines.*)

(Read March 15, 1944.)

Abstract.

The thermal springs are situated 18 miles west-north-west of the town of Nylstroom on the farm Middelfontein and issue from intensely folded sandstones belonging to the Waterberg system. There are seven main sources, having a combined discharge of 414,300 gallons per 24 hours. In the orifices the temperatures range from 27·1° C. to 34·1° C.

Chemical analyses show that the water is only weakly mineralised, the chief constituents being Ca'' and HCO_3'. All the springs are gassy, the gas from one proving to be atmospheric air deficient in O_2 but rich in CO_2.

A line of cold springs occurs 1½ miles north-east of the warm springs, and the geological evidence indicates that both groups are of meteoric origin.

The local inhabitants believe that the thermal waters possess remarkable healing properties.

Introduction.

The early settlers in the southern part of the Waterberg district, Transvaal, discovered that Nature had endowed them with two strong thermal springs. One is decidedly hot and was accordingly named the "Warmbad", the other, which is merely lukewarm, the "Loubad". Warmbad (Warmbaths) has become one of the most popular health resorts in the Union, while the Loubad, as it lies off the main route to the North, has remained completely undeveloped and is practically unknown. It is not among the 45 thermal springs of South Africa listed by Rindl (5) and has not been mentioned in scientific literature.

The Loubad is situated at the intersection of latitude 24° 36′ S. and longitude 28° 11′ E. and lies in the central part of the farm Middelfontein No. 1044 in the Zwagershoek ward of the Waterberg district. The branch railway line to Vaalwater passes through Middelfontein, and the siding

"Loubad" on the farm is 18 miles from Nylstroom and 2¼ miles by road from the springs. Warmbaths is 27 miles away by a direct but very rough road.

The Loubad springs issue on a gently sloping sandy alluvial plain between the spruits known as the Khoduhlou and the Ralekoto, or Rietpoort spruit. These intermittent streams unite and join with Witklip spruit to form the upper part of the Sand River, which is known to the local natives as the Muru.

Middelfontein is subdivided into about twenty small farms, and has a school, post office, and store.

Climate.

Loubad siding and the main thermal spring are 4355 and 4380 feet above sea-level respectively.

No meteorological observations have been made at the springs, but rainfall records were kept for about thirty-five years on a western portion of the farm Rietfontein known as "Waterford". This station was situated some 3 miles east of Loubad siding at an altitude of 4400 feet. Over the periods 1911–1925 and 1926–1939 (9) the average monthly rainfall in inches and number of rainy days were:

Period.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Year.
1911–1925	0·41 2	1·95 5	3·49 7	4·10 8	5·16 10	2·88 7	3·46 7	1·08 3	0·57 2	0·14 1	0·25 1	0·56 1	24·05 54
1926–1939	0·50 2	1·63 5	3·38 7	3·81 8	4·57 8	3·77 7	2·82 6	1·34 3	0·59 2	0·13 1	0·38 1	0·12 1	23·04 49

The rainfall was not measured during the period 1940–1941 owing to the farm "Waterford" having been vacated, and in 1941 the gauge was transferred to Middelfontein, and set up only three-quarters of a mile east of the thermal springs at an altitude of 4390 feet.

The nearest station at which mean maximum and mean minimum shade temperatures have been recorded is Nylstroom, which lies some 400 feet lower than the Loubad springs. The average results for a period of fifteen years are (10):—

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Year.
Mean Max.	81	84	84	84	84	83	81	78	74	70	69	74	79
Mean Min.	48	54	58	60	61	60	57	50	41	36	35	40	50

DESCRIPTION OF THE SPRINGS.

The Loubad group consists of seven thermal springs. Four of them rise on portion M of Middelfontein and are used for irrigation purposes by the owners of the water rights. The most northerly and strongest of these four is the "Bad" (Bath or Bathing pool), from which the farm takes its popular name. One hundred and twenty feet due south of this Bathing pool lies a fairly strong spring which, as it is characterised by more vigorous ebullitions of gas than the others, is called by the local farmers the "Borrelgat", *i.e.* the bubbling hole. In nearly the same line and 140 feet south-west of the Borrelgat is a rather weak source for which there is no local name; it will be referred to in this paper as the "South spring". The remaining spring on portion M lies 30 feet north-west of the Borrelgat and has only a very small discharge.

The fifth spring is situated 260 feet due east of the Borrelgat. It lies on portion N of the farm and is known as "Lewis' spring", after the owner Mr. G. Lewis who uses the water for domestic purposes.

Springs six and seven emerge in a dense poplar thicket that flanks the Khoduhlou spruit some 300 yards to the west of the Bathing pool. They are on Mr. M. Swart's portion F of the farm, and it is proposed that the one near the west bank be called "Swart's spring" and the one on the east bank the "Poplar spring". Some ten years ago, according to Mr. Swart, there was another outlet on the west bank which was dug out and used as a bath by the farm natives; owing to undercutting during floods, however, it now issues in the bed. In this part of the spruit there is a permanent deep pool, and neither the temperature nor the flow of the submerged source could be measured. A straight line joining Swart's spring and the Poplar spring passes through the alleged "drowned spring", and where its northern extension again crosses the Khoduhlou spruit about half a mile to the north the spruit water is stated to "smoke" on cold winter mornings, which seems to indicate the presence of other submerged thermal sources.

All the springs bubble intermittently, the strongest surges of gas being emitted by the Borrelgat, Poplar, and Swart springs. All are floored with pale reddish-coloured sand kept in a state of constant agitation over the major vents, which simulate miniature active volcanoes.

The elevation of the surface of the water in the Bathing pool was determined by taking the mean of several aneroid readings based on Loubad siding and, using this as a datum, the heights of the other springs were measured by means of an Abney level. The greatest difference is between the Poplar and Lewis springs, some 18 feet. (See Table p. 156.)

The sources of the main spring line, *i.e.* the Bathing pool, Borrelgat and

South springs, and the furrows leading from them, are surrounded by reeds * up to 15 feet high which provide nesting places for hundreds of birds whose presence adds considerable charm to otherwise rather uninspiring surroundings. Waterfowl (Black crakes) often alight within a few feet of the bather and scurry away into the reeds apparently quite oblivious of his presence. Catfish ("Barbers", *Clarias* spp.), kurper, and mosquito fish are often to be seen in the main pools and the furrows draining them. Specimens of the kurper were identified by Dr. V. FitzSimons of the Transvaal Museum as *Tilapia sparrmanni* A. Smith and *Haplochromis philander dispersus* Trewavas, while the mosquito fish is *Haplochilus carlislei* v. d. Horst, a species previously known only from the Aapies River, Pretoria.

Algae grow prolifically, and away from the actual orifices the sand is covered with a layer of ooze composed of algal growths and rotting vegetation. Specimens of algae from the Borrelgat and Bathing pool were submitted to Miss E. L. Stephens of the University of Cape Town, who identified the long greenish-brown threads as *Melosira* and the blue-green slime as *Oscillatoria*. The algae are quite harmless.

The Bathing pool is a natural pool-spring about 20 feet across and 3 feet deep. East-west striking, practically vertically disposed Waterberg sandstone projects through the flooring sand at several places and the warm water issues from about 25 orifices or eyes arranged along north-south fractures.

Although trains of gas bubbles rise spasmodically from all the eyes, much is enmeshed in the sand and is only freed when disturbed. A few minutes after entering the pool the bather's skin becomes covered with myriads of gas bubbles which have the effect of increasing the sense of warmth.

The pool is neglected and no dressing-rooms or similar amenities exist.

The Borrelgat is a very shallow natural pool some 14 feet across in which rocks can be felt 4½ feet under the quicksand. The pool bubbles vigorously at short intervals near its south end, while an east-west striking line of about 30 small eyes can be made out near the north bank.

Some 30 feet to the north-west is situated a small warm spring the flow of which is led into the Borrelgat's furrow.

The South spring issues at the top end of the vlei and its water is led into the Borrelgat.

Lewis' spring is a small artificial pool some 8 feet across and 10 inches deep. According to Mr. Lewis it was originally only a seepage. Because of its use as a source of domestic water-supply it is also referred to as the "Drinkfontein".

* Mr. R. G. N. Young of the Dept. of Agriculture identified specimens of the reeds and the predominant vlei grass as *Phragmites communis* Trin. and *Imperata cylindrica* Beauv.

Swart's spring has been dug out in firm clayey soil to form a bath 5 feet by $2\frac{1}{2}$ feet by 2 feet deep; it is, however, very seldom used as such. It lies 18 feet from the bank and the water level is $5\frac{1}{2}$ feet above that in the spruit when the latter is flowing normally. There is a seepage of warm water

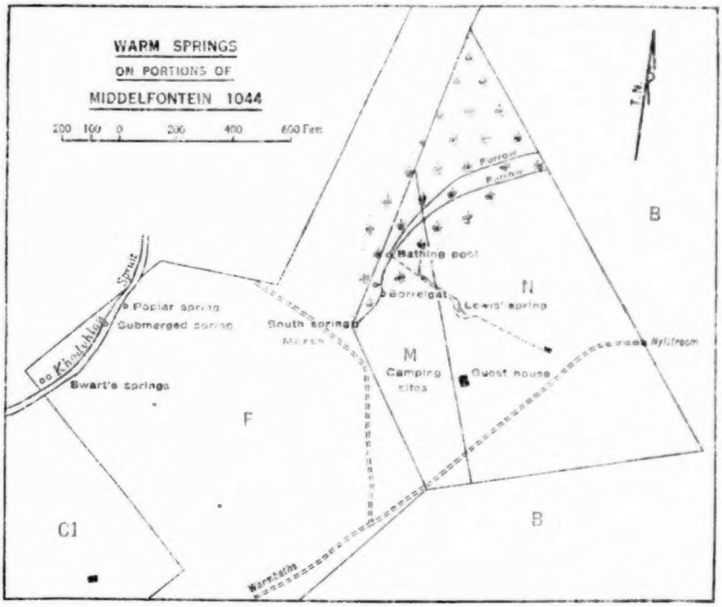

Fig. 1

20 feet to the north-east, hence on the map (fig. 1) the locality is shown as "Swart's springs".

The Poplar spring issues 10 feet from the east bank of the Khoduhlou spruit, and as it is only 3 inches above the normal summer level of the spruit it is often submerged. A rod can be pushed into the eyes for 5 feet before any resistance is felt.

In times of drought, when the Khoduhlou ceases to flow, the water from the Poplar and Swart springs is used for irrigation.

Flows.

A **V**-notch was used to measure the discharges of the various springs. Save in the cases of the strongly flowing Bathing pool and Borrelgat, the notch was placed within a foot or two of the natural outlets, and seepage

losses were thus reduced to a minimum. Owing to the marshy nature of the ground near the Borrelgat the notch was set up 50 feet away in the outlet furrow, and the flow of the small warm spring lying 30 feet to the north-west of the Borrelgat was perforce included. This was, however, deemed advantageous, as in the event of Loubad being developed as a health resort the two would probably be united to form a single pool.

The gauging of the Bathing pool proved somewhat difficult. At the point of emergence from the pool the outlet furrow is 5 feet wide and 3 feet deep, and as the surroundings are completely water-logged leakage around the **V**-notch plank could not be prevented. Accordingly the flow was measured in the furrow 380 feet below its exit from the pool. In order to estimate the percentage loss by soakage in this distance, the flow of the Borrelgat furrow was remeasured 400 feet below the place where the **V**-notch was first installed. The loss amounted to 10 per cent., and the measured discharge of the Bathing pool was accordingly increased proportionally.

The flows of the various springs are given in the following Table, and it will be seen that the combined yield is approximately 415,000 gallons per 24 hours.

FLOWS.

Spring.	Elevation (Feet).	Flow (Imp. Galls. per 24 Hrs.).	Magnitude (Meinzer's Classification).
		Oct.–Nov. 1943	
Bathing pool . . .	4380	280,000	4
Borrelgat . . .	4382½	100,000	5
South spring . . .	4385	13,000	6
Lewis' spring . . .	4394	1,350	6
Poplar spring . . .	4376	18,000	5
Swart's spring . . .	4382	1,950	6
		414,300	

If a spring is cleaned out, opened up, and effluent seepage prevented the flow as measured at the outlet invariably increases. Under Transvaal conditions the relative increase may amount to several per cent.: for example, the mean daily discharge of the Sterkfontein spring near Irene increased from 1·40 to 1·67 million gallons * after it had been prepared in 1943 as an additional source of water for Pretoria city, *i.e.* an increment of about 19 per cent. The true combined daily yield of the Loubad warm springs is

* Information kindly furnished by the City Engineer, Pretoria.

thus probably not far short of half a million gallons, which is about three times as much as that of the Warmbaths spring. Of the better-known South African thermal springs only those at Aliwal North and Florisbad have stronger flows.

In the Borrelgat gas is emitted at the rate of about 28 cubic feet (800 litres) per 24 hours, while the combined yield of all the springs is probably in the vicinity of 42 cubic feet (1200 litres).

Temperature Measurements.

The temperatures of the various springs have been taken at irregular intervals over the period 1940–1943. Two standardised maximum mercury thermometers graduated in half-degrees Centigrade were used, and for each observation they were embedded in adjoining eyes in the sand floors of the pools. After constancy had been attained it was found that the two thermometers were generally in agreement, while if there was a divergence it never exceeded 0·3° C. These differences are certainly to be attributed to slight variations in the temperature of the water as the higher readings were not connected with a particular thermometer. Such variations are quite characteristic of thermal springs and have been noted in different parts of the world (2, 7).

In the Table only the maximum values recorded on any particular occasion are given.

Date.	Bathing Pool.			Borrelgat.	South Spring.	Lewis' Spring.	Poplar Spring.	Swart's Spring.
	North Eye.	Middle Eye.	South Eye.					
20.7.40	33·8	34·1	..	32·7	..	..	30·5	..
7.6.41	34·1	33·9	33·9	33·0	32·0	33·8	31·3	27·7
9.7.43	33·6	33·8	..	32·6	32·0	32·0	30·3	27·2
26.10.43	33·2	33·2	33·2	32·4	31·7	31·7	30·7	27·2
23.11.43	33·2	33·1	33·2	32·4	31·7	31·7	31·1	27·1

The water in the Bathing pool ranges in temperature between 32·5° C. and 34° C.

As is also the case in Georgia, U.S.A. (2), the springs having the largest discharges issue at the highest temperatures. Lewis' spring is an exception, but in view of its close proximity to the Bathing pool and Borrelgat it is probable that they are all fed by connected conduits.

On 1st November 1943, as a result of exceptionally heavy rain on Rhenosterpoort and Elandsfontein, the Khoduhlou spruit came down in

flood. In the poplar thicket the rise was from 10 to 12 feet, and both the Poplar and Swart springs were submerged for a few hours. After the inundation the temperatures were redetermined, but no cooling was detected.

Physical Properties of the Water.

The water is colourless, non-turbid, odourless and tasteless. Even on perfectly calm days no odour of hydrogen sulphide can be detected.

The specific resistances (resistivities) of the water samples analysed are given at the bottom of the Table on p. 159.

Chemical Analyses.

(a) *Water.*—Samples of water from the Borrelgat, Lewis', and Swart's springs were collected on 7th June 1941 in Winchester glass-stoppered bottles which had each been thoroughly cleaned with water from the spring sampled. These were analysed with the minumum of delay.

The Bathing pool was not sampled owing to the danger of contamination from soap.

The analyst reported that "owing to the low concentration of salts the samples were not sufficient for all the determinations required. It was not possible to determine the dissolved gases and it seems unlikely that the samples will contain Br', I' SO_3'', S_2O_3'', PO_4''' and BO_3'''. The total halogen content varies from 3 to 5 parts per million, and as the I' and Br', if present at all, will be a very small fraction of the total, their concentration will be so small that the determination becomes a rather difficult matter. For determination of total solids all bicarbonates were converted into carbonates during evaporation, and the residue was ignited gently so that the Ca and Mg carbonates were decomposed."

Dr. T. Ockerse of the Department of Public Health collected a sample of water from the Bathing pool in May 1941; only the fluorine content was determined, and as the writer's samples were insufficient for this determination the result was taken over.

Half a litre of water from the Borrelgat, collected on 30th November 1943, was evaporated to dryness and the residue was submitted to Dr. Wasserstein of the Geological Survey for spectrographic examination. In addition to the major constituents, Ca, Mg, Na and K, he found significant amounts of Si, Fe, Ba, Li, B and Sr, and traces of Mn, Al, Pb, Cr and Ag. Sn, As, Sb, V, Zn, Cs, Rb, Ti and Ga were specially looked for in sensitive lines and found to be absent.

As the salts in the water are obviously almost completely ionised the expression of the analyses in terms of hypothetical salines would be meaningless.

Ions.	Borrelgat. Mgm. per Litre.	Borrelgat. N/1000.	Lewis' Spring. Mgm. per Litre.	Lewis' Spring. N/1000.	Swart's Spring. Mgm. per Litre.	Swart's Spring. N/1000.	Superior (north) Spring, Hot Springs, Arkansas, U.S.A. Mgm. per Litre.	Superior (north) Spring, Hot Springs, Arkansas, U.S.A. N/1000.
NH_4' . . .	nil		nil		nil		0·013	·001
Na' . . .	8·2	0·36	8·6	0·37	9·8	0·43	4·40	·191
K' . . .	2·8	0·07	2·4	0·06	2·9	0·07	1·47	·038
Li' . . .	nil		nil		nil		tr	
Mg'' . . .	5·6	0·46	5·5	0·45	4·9	0·40	4·23	·353
Ca'' . . .	26·4	1·32	26·0	1·30	27·6	1·38	37·43	1·872
Ba'' . . .	nil		nil		nil		n.d.	
Mn'' . . .	n.d.		n.d.		n.d.		0·11	·004
Fe'', Al''' . .	tr		tr		tr		0·09	·003
Sum of Cations .	43·0	2·21	42·5	2·18	45·2	2·28	47·743	2·462
Cl' . . .	3·6	0·10	5·4	0·15	3·6	0·10	2·43	·069
Br', I' . . .	n.d.		n.d.		n.d.		tr	
F'* . . .	0·49	0·03	0·49	0·03	0·49	0·03	n.d.	
SO_4'' . . .	tr		tr		tr		7·31	·152
SiO_3'', $HSiO_3'$.	nil		nil		nil		nil	
CO_3'' . . .	nil		nil		nil		nil	
HCO_3' . . .	122·0	2·00	122·0	2·00	128·0	2·10	133·20	2·184
SH' . . .	nil		nil		nil		n.d.	
NO_3' . . .	nil		nil		nil		0·31	·005
NO_2' . . .	nil		nil		nil		0·0010	·000
PO_4''' . . .	n.d.		n.d.		n.d.		0·13	·004
BO_2' . . .	n.d.		n.d.		n.d.		tr	
AsO_4''' . . .	nil		nil		nil		nil	
Sum of Anions .	126·09	2·13	127·89	2·18	132·09	2·23	143·381	2·414
Total sum of ions .	169·09	4·34	170·39	4·36	177·29	4·51	191·124	4·876
H_2SiO_3 . . .	24·6	(0·63)	19·9	(0·51)	23·0	(0·59)	39·90†	
Totals . . .	193·69		190·29		200·29		231·024	
Total solids (gently ignited) . .	92·5		98·3		100·8		n.d.	
Total hardness as $CaCO_3$ . .	89·0		87·6		89·1			
Alkalinity as Na_2CO_3	15·9		13·3		19·6			
pH . .	7·20		7·15		7·20		n.d.	
Specific resistance (ohm cms.) at 60° F. . .	5700		5400		5400		n.d.	

Analyst: C. F. J. van der Walt, Division of Chemical Services.
* Fluorine: W. Sunkel, Division of Chemical Services.
Arkansas spring: J. K. Haywood (8). † SiO_2.

(b) *Gas.*—A sample of the gas issuing with the water from the Borrelgat was collected on 7th June 1941 in a special apparatus made for the purpose by Dr. Groenewoud. Its composition is:—

O_2	11
CO_2	2
CH_4	nil
H_2	nil
N_2 + rare inert gases (by difference)	87
	100

Analyst: C. F. J. van der Walt, Division of Chemical Services.

As compared with atmospheric air the spring gas is deficient in oxygen and rich in carbon dioxide.

The Sand.—The local farmers believe that the sand flooring the springs has been brought up by the warm water. They point out that although several wagon loads have been removed from the Borrelgat from time to time for building purposes the level in the pool has not subsided. Some springs and flowing boreholes do in fact bring up grains of sand in suspension, a good example being the artesian borehole at Jacobs, near Durban. However, if this process operated at Loubad, sand would have been built up around the vents and filled the pools.

The black vlei soil is bounded and underlain by pale reddish sand, and in its ascent the warm water churns up and works over this sand.

Mechanical analyses through Tyler sieves of sand from the Borrelgat and the vicinity of Mr. Lewis' house show that the former is coarser owing to the elimination of the very fine grades.

	Mr. Lewis' House.	Borrelgat.
Retained on 20 mesh (> ·8 mm.)	0·8	0·6
Passes, 20 retained on 28 mesh (> ·6 mm. < ·8 „)	1·4	2·7
„ 28 „ „ 35 „ (> ·4 „ < ·6 „)	7·5	17·0
„ 35 „ „ 48 „ (> ·3 „ < ·4 „)	18·1	30·9
„ 48 „ „ 65 „ (> ·2 „ < ·3 „)	33·1	33·9
„ 65 „ „ 100 „ (> ·15 „ < ·2 „)	26·5	13·9
„ 100 mesh (< ·15 „)	12·6	1·0
	100·0	100·0

Around Loubad the Waterberg sandstone has an average grain size of 0·3–0·4 mm., and it is undoubtedly the source rock of the bulk of the sand in the vicinity of the springs.

Cold Springs.

Middelfontein is a particularly well-watered farm. In addition to the thermal springs and the three intermittent spruits there are numerous cold springs, distributed as shown on the geological map, fig. 2.

Two springs, regarded locally as thermal, issue near the west bank of the Ralekoto spruit about a thousand yards east of the Bathing pool. The more southerly one adjoins the Maalgat (*i.e.* Whirlpool) and is generally submerged after rains, as it lies only a few inches above the normal level of the water in the spruit—4360 feet. The other is situated some two hundred yards to the north and had a discharge of 2700 gallons per 24 hours on 9th November 1943. On the same day the temperatures of the springs were 22·0° C. and 20·9° C. respectively.

Several weak and intermittent springs occur along the banks of the Khoduhlou spruit.

There is a well-defined line of eleven cold springs on the northern slope leading down to Witklip spruit. They issue from northerly dipping Waterberg sandstone and the spring line trends east-west. For convenience they have been numbered from east to west, No. 1 being actually a few feet inside the farm Rietfontein 950. The discharges of the larger ones in November 1943 were:

Spring.	Elevation (Feet).	Flow (Imp. Galls. per 24 Hours).	Magnitude (Meinzer's Classification).
1	4360	4,450	6
2	4360	6,650	6
6	4360	4,000	6
8	4355	8,700	6
10	4350	17,400	5

The combined daily yield is probably in the vicinity of 60,000 gallons. Many seepages occur between the well-defined flowing springs.

The aquifer feeding these springs was intersected at a depth of 40 feet by a borehole at the school. The water rose to 23 feet, and the yield is given as 72,000 gallons per 24 hours.

A partial analysis of water from spring No. 6 collected on 29th November 1943 gave:

Ca'' 4·0 mgm. per litre
HCO_3' 24·4 ,, ,,
pH 7·6

Specific resistance at 60° F. 24,840 ohm cms.

Analyst: W. Sunkel, Division of Chemical Services.

The solutes are thus considerably less than in the thermal waters.

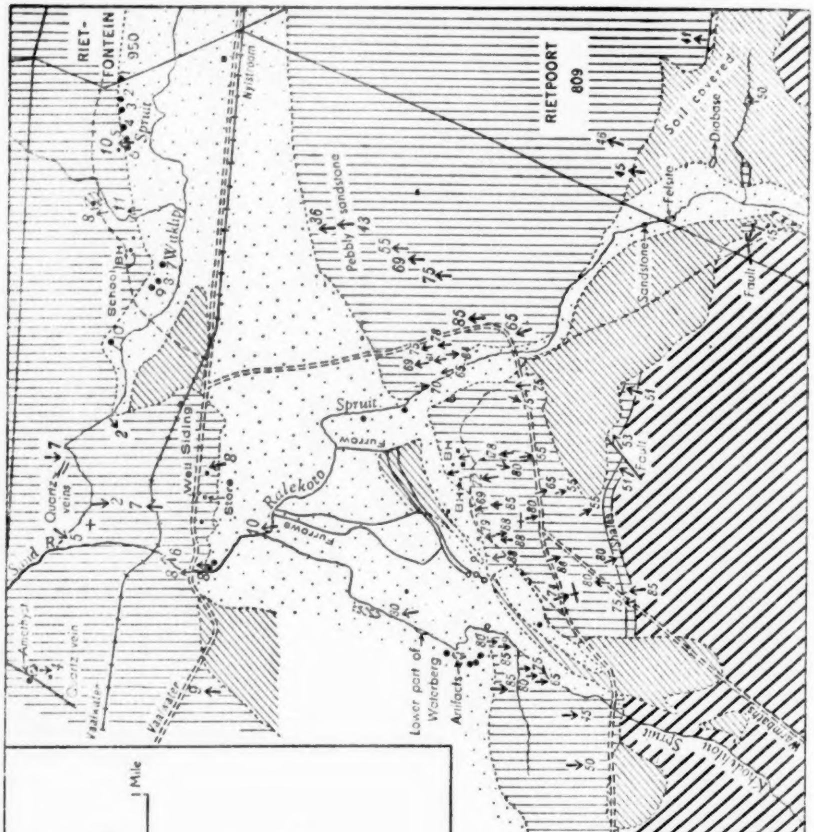
GEOLOGICAL MAP
OF PORTION OF
MIDDELFONTEIN 1044
0
1 Mile
REFERENCE
Sand and alluvium
Ferricrete
Waterberg sediments
Rooiberg felsites
Warm springs
Cold springs
BH Boreholes
RIET-FONTEIN 950
RIETPOORT 809
Ralekoto
Spruit
Furrow
Store
Well Siding
School
Quartz veins
Quartz vein
Lower part of Waterberg
Artifacts
Pebbly sandstone
Nylstroom
Sandstone
Felsite
Soil covered
Diabase
Fault
Shales
Rubble strewn
T.N.

Fig. 2

Geology.

Middelfontein 1044 (former number 2027) falls within Geological Survey sheet 10 (Nylstroom), published in 1912, but no mention of the thermal springs is made in the Explanation. The area was remapped on aerial photographs in 1943. The area shown on the large-scale locality map, fig. 1, lies in the south-central part of the geological map, fig. 2.

The northern part of Middelfontein is made up of Rooiberg felsites, Waterberg sediments, post-Waterberg diabase, river gravels, ferricrete, sand, and alluvium. Only the Waterberg sediments are of direct interest in connection with the origin of the springs.

In this area the base of the Waterberg system is marked in many places by peculiar conglomerates, or "sedimentary breccias", made up of angular pebbles and small boulders set in a hard fine-grained matrix. These breccias, which are impersistent and seldom exceed 20 feet in thickness, are followed by maroon shales having a maximum thickness of 100 feet. The shales were separately mapped in the south central part of Middelfontein, but in the west they are hidden beneath ferricrete and surface drift. Medium-grained, dull purple sandstones and quartzitic sandstones which are invariably current-bedded and commonly ripple-marked, form the remainder of the system. Pebbles are seldom encountered and no conglomerates occur. Some of the sandstones contain clay-pellets which are so numerous in places as to constitute clay-pellet conglomerates. Feldspathic sandstones do occur, but most of the dull white grains tested proved to be chert. Veinlets of quartz, quartz associated with specularite, and psilomelane were also found.

Around Loubad there has been intensive folding, and the plane of contact between the Waterberg sediments and the Rooiberg felsites on Kralingen 1206 and de Naauwte 1204 is repeatedly overtilted. At the western end of Middelfontein the sequence is normal, but the dips are very steep. About half a mile within Middelfontein the strata are again overfolded, and the inversion persists about as far as the Warmbaths-Loubad road. Farther east the succession is again normal.

Beds near the base of the Waterberg system are exposed where the Khoduhlou spruit cuts across the crest of a sharp anticline three-quarters of a mile north of the contact with the Rooiberg felsites. Farther east in the vicinity of the Bathing pool the sandstones are isoclinally folded. The fold axes pitch to the east.

North of the warm springs the dips become less steep and the structure is a shallow syncline. (See section, fig. 3.)

Mellor (3) observed the overtilting on Middelfontein 1044 and de Naauwte 1204, and suggested that the absence of the conglomerate which occurs near

the base of the Waterberg system on Rietpoort 913, Kralingen 1206, Rhenosterpoort 1122, and Rietpoort 809 might be due to "faulting along the base of the sandstones, where vertical or overtilted dips prevail". However, the presence of the relatively persistent basal shales shows that no such faulting has taken place and that the conglomerate has merely died out.

A strike fault on the western part of Rietpoort 809 has resulted in a minor duplication of the sandstone, while on Middelfontein the basal beds of the Waterberg system have been slightly displaced.

Diabase was found in place near the Ralekoto spruit in the south-east part of the area, but owing to the obscuring ferricrete and sand the intrusion could not be followed.

Ferricrete patches occur all over the area, while the central parts are covered by sand.

Middle Stone Age implements of the Pietersburg culture were found on the west bank of the Khoduhlou spruit in an eroded layer of ferricrete about a foot thick lying 18 to 20 feet above the bed of the spruit. At the bottom of the bank a layer of gravel about 5 feet thick contains implements of Fauresmith age.

Origin and Depth of the Springs.

The Loubad thermal springs are undoubtedly of meteoric origin. This is shown firstly by the fact that they emerge from Waterberg (Cambrian ?) sandstone in an area where the latest igneous activity is represented by diabase intrusions probably of pre-Karroo age. Furthermore, the water issues at relatively low temperatures and contains only spectroscopic amounts of boron, while arsenic is entirely absent. Many hydrologists have stated that these elements are usually but not necessarily indicative of water of juvenile origin. Loubad water is in fact only weakly mineralised and would be regarded by most chemists as an "indifferent" or "simple thermal water".

In chemical composition it is typical of sandstone waters. The preponderant cations present, Ca'', Na' and K' are probably derived from feldspars, while diabase intrusions possibly supply most of the Mg''. The dominant anion HCO_3' has its source in atmospheric CO_2, while the Cl', which is present to the extent of only 4 to 5 parts per million and is subordinate to Na', may well be of cyclic origin. The virtual absence of Fe'' and Al''' is hardly surprising as they are only found in appreciable amounts in acid waters, or in alkaline waters if they be free from oxygen. Sulphate is present only as a trace, and in this connection it is interesting to note that Saratoga spa water (6) with dominant ions HCO_3', Na', Cl' and Ca'' does not contain even a trace of SO_4''.

The silica, an important constituent in Loubad water, can be explained by the direct solution of quartz and by the fact that colloidal SiO_2 is liberated during the kaolinisation of feldspars by oxygenated carbonated waters.

The source province of the Waterberg sandstones undoubtedly included large areas of Bushveld granite in which fluorspar is commonly encountered both as a minor accessory and in veins. It seems likely that detrital fluorspar, which is slightly soluble in alkaline waters, is responsible for the small amount of fluorine present.

The spring gas is air deficient in oxygen but rich in carbon dioxide. This excess of CO_2 prevents the deposition of tufa which, by analogy with the Arkansas spring of similar composition (8), might have been expected. It is estimated that the springs at Loubad bring up about 150 tons of dissolved salts per annum.

The quartzitic sandstones around the orifices in the Bathing pool exhibit a shiny surface due, however, to the polishing action of the water and not to the deposition of silica.

An artesian system capable of returning to the surface meteoric water heated to the observed temperatures must now be sought. The N.E.-S.W. geologic section (fig. 3) shows the intake areas and the course postulated for the subterranean flow: to avoid distortion the vertical scale has not been exaggerated. The warm springs flow from fissures at or near the crest of a sharp anticline and are "fissure siphon artesian springs" rising under a hydrostatic head of about 800 feet (friction loss neglected). The main fissures trend about north-south as is indicated by the distribution of the springs. It seems probable that the confined water percolates through the sandstones immediately overlying the impervious basal shales of the Waterberg system or the equally

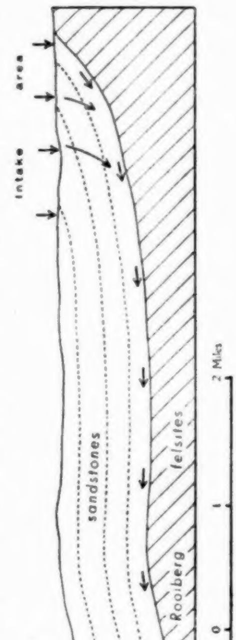

FIG. 3.

impervious Rooiberg felsites. At the intake area ingress is facilitated by the presence of fractures and shatter belts associated with the strike faults near the northern contact of the Waterberg sandstones with the Rooiberg felsites (3). There is no definite confining layer.

The maximum depth in the artesian basin is about 3600 feet. Unfortunately, however, no geothermal measurements have been made in boreholes in the Waterberg system. Bullard's (1) figure for the mean heat flow in South Africa is $1{\cdot}16 \times 10^{-6}$ cal./cm.^{2} sec., while sandstones of similar texture and porosity to those of the Waterberg system have thermal conductivities of about 0·0075 cal./cm. sec. °C. Assuming the applicability of these figures and a mean ground temperature of 19° C., the geothermal step in the vicinity of Loubad is about 220 feet per 1° C. The water at the bottom of the syncline would thus be heated to a temperature of about 36° C. Water flows rapidly in fractures and the loss of heat in ascent would not be excessive.

Observed and calculated temperatures are thus in accord for the strongly flowing springs. The weaker ones and the small cold springs in the vicinity of the Maalgat are probably of shallower origin or the water may have been cooled through ascent in more tortuous passage-ways.

The cold springs near the northern bank of Witklip spruit are normal siphon artesian springs and the water in likelihood attains a maximum depth of only 300 feet. There is no well-defined impervious layer isolating this small system.

Medicinal.

According to the local inhabitants bathing in the spring has proved extremely beneficial in the treatment of flesh wounds, sores, minor burns, blood poisoning in its early stages, and asthma.

The fluorine content (0·49 mgm. per litre) is not high enough to cause fluorosis and the water is thus eminently suitable for internal administration. In this connection it is interesting to note that other thermal springs in the Waterberg district, Warmbaths, Die Oog (Rietfontein 1042), and Vischgat 1091 contain respectively 11·02, 5·0, and 5·37 mgm. of fluorine per litre * and are therefore definitely contraindicated as sources of drinking water.

Classification.

(a) *Physical.*—Clear. Subthermal. Radioactivity undetermined.

(b) *Chemical.*—A very dilute, somewhat siliceous, gassy carbonate water. Non-sulphuretted.

* From unpublished analyses by Mr. W. Sunkel, Division of Chemical Services, for Dr. T. Ockerse of the Department of Public Health.

Total ionic concentration N/1000, 4·37.

Ionic concentrations of characteristic constituents N/1000:—

Ca'' 1·33, Mg'' 0·44, HCO_3' 2·03.

On Chase Palmer's system (4) the average of the three analyses may be expressed thus:—

Properties.*	Loubad.	Arkansas.
Primary salinity	6·5	9·2
Primary alkalinity	13·9	0·2
Secondary alkalinity	79·6	90·6
	100·0	100·0

* *Primary salinity* is caused by the chlorides and sulphates of the alkalies.
Primary alkalinity is due to alkaline bicarbonates.
Secondary alkalinity is the property associated with bicarbonates of the alkaline earths.

The water is moderately hard. Total hardness as $CaCO_3$, 88 p.p.m. Permanent hardness nil.

(c) ***Medical:***

Pharmacological Properties.—Weakly antacid, mildly diuretic, depurative.

Physio-therapeutic Properties.—Hypotonic. Fresh, *i.e.* the water is not conveyed in pipes and one bathes in an actual spring at its natural temperature. The water is practically at the indifferent temperature (93–94° F.) and is therefore sedative in its action.

Comparison with other Springs.

As far as it is known at present not one of the 97 thermal springs in the Union or Southern Rhodesia has a composition even approximating to that of the Loubad group. There is, however, a close resemblance to the Superior (North) spring, one of the many that issue from sharply folded Lower Silurian sandstones and shales at the well-known health resort Hot Springs, Arkansas (8). (See table of analyses, p. 159.)

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STYLOCEPHALUS INGERI, SP. NOV., A CEPHALINE GREGARINE FOUND IN THE GUT OF *GONOCEPHALUM ARENARIUM* (COLEOPTERA).

By Alfred J. Gibbs.

(With twenty-six Text-figures.)

(Read April 18, 1945.)

The Insect Host.

The beetle *Gonocephalum arenarium* (Order Coleoptera; Family Tenebrionidae) is a root-feeding insect common in the Cape Peninsula. It can frequently be found sheltering beneath stones. Only the mature insect has been observed. It is not known whether the larval and nymphal stages occur in the same environment as the adult; but in any case they have not been recognized, and no description has been found in the literature enabling them to be identified.

The digestive tract consists of a short, narrow upper-gut which leads abruptly into a much wider mid-gut or stomach. At the posterior end there is a constriction leading into the hind-gut. Six malpighian tubules connect with the mid-gut a short distance anteriorly of the hind-gut.

The hosts of *Stylocephalus longicollis* Stein, and *S. oblongatus* Hammerschmidt, are *Blaps mortisaga* and *Olocrates gibbus* respectively. Both of these beetles belong to the family Tenebrionidae, but neither are found in South Africa.

The Trophozoite Stage.

About 80 per cent. of the insects examined were found to be infected. It is probable that the early stages of development usually take place in the gut of the larva. Many sections of the gut of the adult have been studied, but trophozoites were never found at a stage previous to the differentiation of the body into protomerite and deutomerite. The very few adherent forms observed were always attached to the cells of the mid-gut, and it is in this portion of the digestive tract that the complete development of the gregarine, until the stage of cyst-formation, takes place.

The youngest trophozoite found measures about 16 μ in length. Its deutomerite is globular, measuring some 12 μ in diameter, while the septum

dividing it from the protomerite is faintly visible. The epimerite is not clearly defined at this stage. At first the parasite has little effect on the gut-cells; the cilia are destroyed and a slight depression is formed in the immediate vicinity of the parasite, but the greater part of the body of the gregarine lies within the lumen (fig. 1). As growth continues there is destruction of the gut cells with the formation of an intercellular concavity large enough to contain the trophozoite completely (fig. 2). The nucleus exhibits the same characteristics at all stages, it is an elongated ovoid and the chromatin is in the form of a number of spheroidal bodies.

In fresh material examined in saline the youngest forms found are almost hyaline, ovoid bodies measuring about 36 μ in length, with an epimerite of about half the body-length. The epimerite has a short neck, swelling out at the end to a bulbous tip. The septum can be made out. The nucleus is large, and usually lies obliquely across the deutomerite (fig. 3). As the gregarine increases in size it becomes progressively more opaque, and at the same time the differentiation between the granular endoplasm and the clear ectoplasm becomes apparent. The deutomerite meanwhile elongates and tapers posteriorly to a blunt point (fig. 4). The neck of the epimerite of the larger trophozoites is spindle-shaped and exhibits very fine longitudinal corrugations or striations on its surface (fig. 5). Immersed in saline the epimerite is waved from side to side and quickly discarded. The tip of the protomerite afterwards exhibits a raised, flattened thickening of the ectoplasm, through which passes a minute pore leading to the granular interior. Fig. 6 shows an almost mature gregarine after the loss of the epimerite. Large specimens measuring up to 560 μ in length have been found with an epimerite. The protomerite : deutomerite length ratio alters considerably with growth, that of young trophozoites being about 1 : 3, while mature forms have a ratio of about 1 : 35. When the digestive tract is removed from the insect, the gregarines are always found lying lengthwise against the gut-wall.

Gametogony.

The first step in the process of gametogony would appear to be the discarding of the epimerite by the mature trophozoite. The protomerite of the gametocyte is dome-shaped, and the terminal pore ceases to be visible. At its anterior end the deutomerite broadens considerably, its maximum width being about 95 μ (fig. 7). Such forms may attain a length of over 2 mm. The formation of a pre-gametocystic association has not been observed, and if it does occur must do so immediately before encystment.

When cyst formation takes place, two gametocytes of equal size secrete around themselves a transparent wall with which they are in contact, but

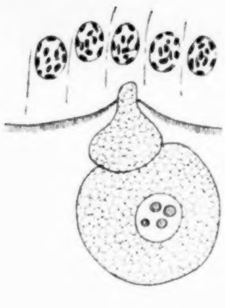

Fig. 1

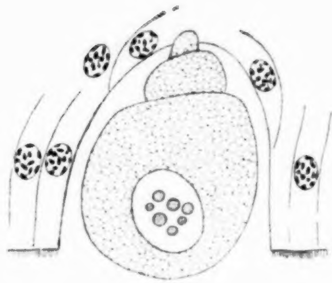

Fig. 2

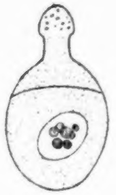

Fig. 3

Fig. 5

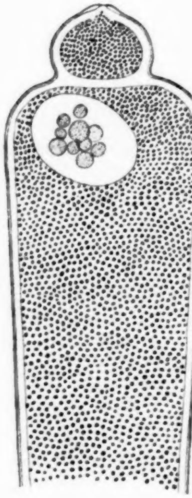

Fig. 6

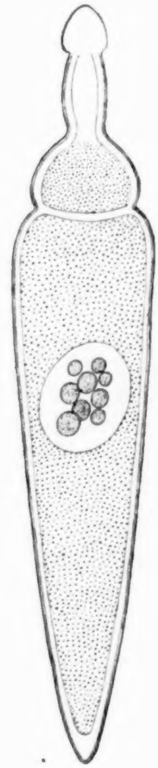

Fig. 4

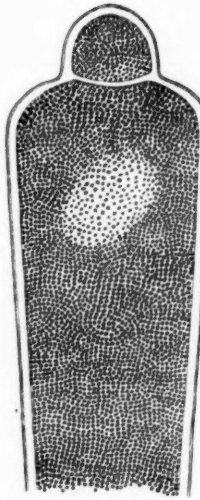

Fig. 7

Fig. 1.—Section of mid-gut showing young trophozite. × 1750.

Fig. 2.—Section of mid-gut showing destruction of gut-cells by larger parasite. × 1750.

Fig. 3.—Young free trophozoite. × 500.

Fig. 4.—Larger trophozoite. × 325.

Fig. 5.—Epimerite showing striæ. × 325.

Fig. 6.—Almost mature form after loss of epimerite. × 325.

Fig. 7.—Gametocyte. × 325.

not adherent. This wall is studded over its entire surface with minute "bosses". The tops of the elevations are flattened, or even slightly indented. Fig. 8 shows a cross-section of the cyst-wall under high power. Cysts are found only in the hind-gut, and when artificially removed are spherical, measuring about 220 μ across, while the contents can easily be observed on account of the high degree of transparency of the wall. The two gametocytes practically fill the cyst, each being roughly hemispherical while the nuclei are masked (fig. 9). When naturally voided with the dejecta the wall becomes somewhat less transparent, and the cyst is frequently distorted, but the gametocytes present a similar appearance. In view of the fact that the gut is frequently heavily infected with trophozoites and gametocytes, the number of gametocysts voided is exceedingly small. Usually not more than two cysts could be recovered from the dejecta of 50 insects after 12 hours; often none were discovered.

Gamete Formation.

Nuclear division takes place within each gametocyte before the cysts are passed out of the gut of the host. The youngest cyst sectioned exhibited a few nuclei spaced throughout each associant. These nuclei were ovoid, measuring some 15 μ in length and had a relatively massive karyosome of about 4 μ in diameter situated towards one end (fig. 10). Later, the nuclei are more numerous, and are considerably smaller. They become more spherical, measuring about 4 μ in diameter, and exhibit an eccentrically placed karyosome (fig. 11). At a still later stage they tend to arrange themselves in rows or chains, both around the periphery and in the more central portions as well. These nuclei do not exhibit a karyosome, the chromatin being disposed in peripheral flakes (fig. 12).

After 24 hours, conical processes of hyaline protoplasm are formed at varying points on the surface of each gametocyte (fig. 13). At first they measure about 7 μ across the base, with a similar measurement from the base to the apex, but they soon increase in number, becoming at the same time smaller and more rounded in outline. In two days the entire surface of each encysted gametocyte is covered with these immature gametes or gametids. Meanwhile, the outline of both associants commences to be broken by deep indentations, and this process of lobulation, as it were, continues until, when viewed in optical section, the gametocyst takes on an appearance similar to that illustrated in fig. 14. The demarcation between the gametocytes is always apparent if the cyst is viewed from the correct angle. As far as can be observed, the entire mass of each gametocyte is surrounded by hyaline processes. Until just before the commencement of motility, the appearance of the gametes developed by both associants is

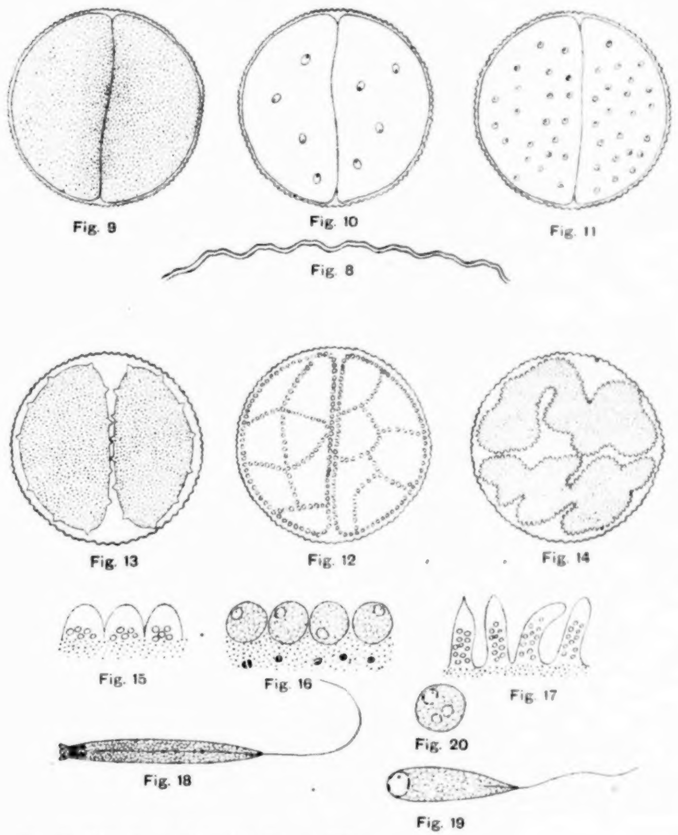

FIG. 8.—Section of gametocyst-wall. × 550.
FIG. 9.—Newly formed gametocyst. × 135.
FIG. 10.—Section of cyst showing early nuclear divisions. × 135.
FIG. 11.—Nuclei of above at later stage. × 135.
FIG. 12.—Section of gametocyst showing chain-formation of nuclei. × 135.
FIG. 13.—Early conical protuberances formed on surface of gametocytes. × 135.
FIG. 14.—Optical section of gametocyst just before the liberation of gametes. × 135.
FIG. 15.—High-power view of gametids in living state. × 1100.
FIG. 16.—Section of gametocyst showing gametids and blocks of residual chromatin. × 1100.
FIG. 17.—Living male gametes just before liberation. × 1100.
FIG. 18.—Fusiform type male. × 1100.
FIG. 19.—Pear-shaped male. × 1100.
FIG. 20.—Female gamete. × 1100.

identical, both groups appearing as clear tongue-shaped "buds", and showing a few round refractile granules near the main body of the associant (fig. 15). Coincident with the breaking up of the gametocytes, a thin clear liquid is liberated which fills all interstices in the cyst. As previously pointed out, the associating gregarines at first nearly fill the cyst and there is little free liquid. When breaking-up occurs, however, there is shrinkage and the release of liquid.

Sections of the cyst at this stage show that the peripheral processes are now cells measuring about 5·5 μ across, the nuclei being situated near the border of the cytoplasm. Small, dense concentrations of chromatin lie behind the peripheral cells within the parent cytoplasmic mass in certain areas of the cyst. They average about 2 μ across. There does not appear to be a differentiation of the cytoplasm corresponding to each chromatin group. They probably represent chromatin not required in the sexual phase (fig. 16).

About the third day following egestion by the host, there is a rapid lengthening of the gametes on one gametocyte. The tip of each remains hyaline, but the rearmost portion, nearest to the parent mass, is coarsely granular (fig. 17). They start a waving movement which increases in vigour until they break free into the liquid contents of the gametocyst. They exhibit incessant bending movements after liberation, but the rate of progression, with the hyaline tip foremost, is slow. The posterior part of the body tapers and ends in a fine motile filament of approximately the same length as the body. Its function is obscure, as although there is whipping of the filament, the gamete appears to derive such powers of locomotion as it possesses more from vigorous bending movements of the body.

In describing the motile gametes of *Stylorhynchus longicollis* and *S. oblongatus*, Léger (1904) states that two distinct types of spermatozoides, as he terms them, can be seen when examined alive. He differentiates them according to shape, one being pear-shaped while the other is more elongated and is referred to as the fusiform type. In the present species both of these types can be observed and this terminology will be used. In the living state, however, they can best be differentiated by the appearance of the cytoplasm, that of the fusiform type being coarsely reticular while the cytoplasm of the pear-shaped type exhibits spherical granular inclusions. Léger also states that the nuclei of the pear-shaped gametes and an eccentrically situated karyosome, "like a brilliant grain", can be seen in the living state, but this has not been observed in the present instance.

These motile gametes will subsequently be referred to as males. They become free before those developed on the opposed gametocyte, which are immotile and will be termed females. Soon after the release of the males into the surrounding liquid they find their way to all parts of the cyst, and

may possibly assist mechanically in bringing about the detachment of the females from the parent body. Léger suggests that the newly liberated males may secrete a substance which stimulates the liberation of the females, and in support of his hypothesis quotes an instance in which the male gametocyte had died, and the females subsequently failed to become detached. It has not been possible to confirm this theory, as in a similar case the females became free and the residual material of the female parent body dissolved. Possibly in the case referred to by Léger, the death of the male gametocyte had taken place at an earlier stage, and substances detrimental to the complete development of the females might have been emitted into the surrounding liquid. After liberation of the gametes, both male and female, the residual material of each gametocyte becomes completely dissolved in about one hour, and since the males are released before the females, it frequently happens that the residual material of the male gametocyte has completely disappeared while the female gametes are still attached to the mother body. Finally the cytoplasmic residuum disappears in its entirety, leaving the gametocyst filled with fluid which contains the gametes.

Appearance of Gametes in Stained Preparations.

Smear preparations of crushed cysts were found more satisfactory for the study of the cytology of the gametes than sections. Fixation in Schaudinn's solution and staining in Ehrlich's hæmatoxylin and eosin were used throughout the work. The two types of males are clearly differentiated in stained preparations. The longer, fusiform type measures about 21 μ with a filament of similar length. The nucleus is situated at the hyaline end and consists of a compact mass of chromatin which appears quadruple in structure. There is no apparent nuclear membrane. Two minute anteriorly directed cytoplasmic cones lie on either side of the nucleus. These, however, can only be seen when the gamete is suitably orientated (fig. 18). The cytoplasm is frothy and is enveloped in a very delicate ectoplasmic pellicle. Léger states that in this type of male the flagellum-like filament originates from two roots situated near the nucleus and continues as two approximately parallel threads to a point near the posterior tip of the body, where they unite to form the motile filament. This has not been confirmed, although in some cases it has been possible to follow the path of a single filament to within a short distance of the nucleus.

The pear-shaped gamete presents a very different appearance; it is shorter and broader (14 μ by 3·5 μ) and the nucleus is of the vesicular type with a small eccentric karyosome. The cytoplasm is alveolar, more

densely staining, and is bordered by a distinct pellicle. According to Léger, the flagellum-like organelle can be seen to pass upwards as an axial filament for practically the whole body-length, but in the present species it could only be traced for a short distance within the body (fig. 19). This form constitutes the majority of the male gametes and it is the type which copulates with the female.

The female is a spherical cell measuring about 5·5 μ across, with a large vesicular nucleus near the margin of the body. The chromatin is disposed peripherally around the nuclear membrane, while a small karyosome is situated at one side. The cytoplasm is similar to that of the fertile male cell and usually shows one or more vacuoles (fig. 20).

Fertilization and Evolution of Zygote.

Fertilization does not commence to take place for some hours after the complete liberation of both male and female gametes. During that period the males appear to have no affinity for the females. Accurate observation of what actually happens is a matter of great difficulty, principally on account of the vigorous movement which takes place throughout the gametocyst. Copulation begins about the fifth hour and requires 4 to 5 hours for its completion. The fusion of the individual pairs appears to be a very rapid process, and one which is very difficult to observe among the swirling mass of gametes. The union is lateral, the female being applied to the middle of the elongated body of the male. Motility ceases practically as soon as fusion has taken place, although the motile filament is retained for a short time afterwards. They later become rounded with a diameter of 9 μ, and the filament is lost. As the number of copulations increases, the activity within the cyst diminishes, and finally it can be observed that there is an apparent surplus of males, which continue, for some hours, to buffet the zygotes. These males are always of the fusiform, infertile type. Fusion of the nuclei does not take place until the pair have attained the rounded stage. Fig. 21 (*a*) and (*b*) shows the rounded form before and after the fusion of the nuclei. If a gametocyst is ruptured in saline after the cessation of motility it is found that the zygotes adhere to each other in chains, and that the point of contact between adjacent individuals is always the same in relation to the synkaryon (fig. 22). The mechanism resulting in this orientation of the zygotes is not easy to understand. Even after chain-formation they continue to be jostled by the fusiform males. After the cyst has become quiescent, these infertile gametes become rounded and the motile filament is lost; the frothy character of the cytoplasm is retained. Pear-shaped males are never observed at this stage. Before activity ceases, solid matter begins to gather in the centre of the cyst, where a round, dark

area is formed. This matter later becomes enveloped in a membrane, and forms the pseudocyst.

About 24 hours following the liberation of the gametes, the zygotes lose their spherical form, one side becoming somewhat flattened while the

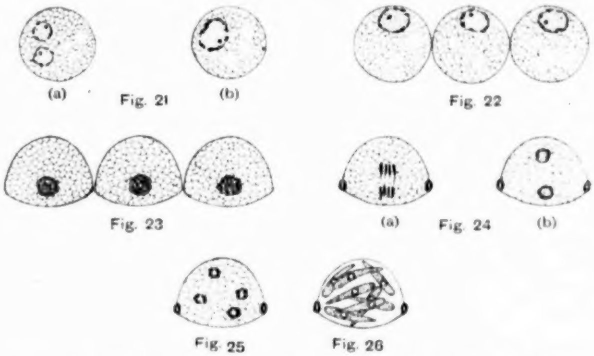

FIG. 21.—(*a*) Fused pair with separate nuclei. × 1100. (*b*) Zygote showing synkaryon. × 1100.

FIG. 22.—Rounded zygotes in chain formation. × 1100.

FIG. 23.—Purse-shaped sporoblasts before first nuclear division. × 1100.

FIG. 24 (*a*) and (*b*). —First nuclear division of sporoblast. × 1100.

FIG. 25.—Second division. × 1100.

FIG. 26.—Sporocyst showing sporozoites. × 1100.*

* Figs. 1, 2, 10, 11, 12, 16, 18–26 stained with Ehrlich's hæmatoxylin and eosin; all other figures drawn from unfixed material.

other becomes dome-shaped. The nuclei are in every case situated near the more flattened surface. At this stage the zygote measures about 10·5 μ by 9 μ (fig. 23). This form is retained during subsequent development until the sporocyst stage is attained. There is a considerable interval between syngamy and the first nuclear division; cysts fixed 24 hours after activity contain only mononuclear sporoblasts. By that time, however, the synkaryon has lost its vesicular character and has taken on a spireme appearance. The first nuclear division takes place about 36 hours after the cessation of activity. The chromosome number during that division is four (fig. 24, *a* and *b*). At the same time a cyst-wall is formed, and at the point of contact between the sporoblasts it thickens abruptly and becomes opaque. The second division has not been observed, but quadrinucleate forms have been found. The nuclei are small, with peripheral chromatin, and are evenly spaced throughout the sporoblast (fig. 25). After the second division the wall thickens, toughens, and becomes impermeable to stain. It eventually takes on a brownish tinge. Octonucleate sporo-

cysts have been found in sections in a few cases where the wall has been cut. The nuclei are smaller but similar in characteristics to those resulting from the previous division.

During the maturation of the sporocysts the gametocyst-wall becomes progressively darker and finally turns black. Dehiscence takes place on the fifteenth day, and is by disintegration of the wall, which first becomes brittle, then fractures, and finally falls away in fragments, leaving the sporocysts in a round mass. If immersed in water they float off in long chains. The residual material (pseudocyst) does not appear to act as an "expanding body". It has been found that the cyst does not dehisce if kept in water. Each mature sporocyst contains eight sporozoites. The sporozoite has an elongate body with one blunt, rounded end, tapering at the other to a more pointed extremity. It measures some 7 μ in length by 1·75 μ across the greatest width. The nucleus is situated about the middle of the body or slightly nearer to the blunt end. Sporozoites can be demonstrated by crushing the cyst in Bouin's fixative and staining. By thus fracturing the wall, penetration of the stain becomes possible and the internal contents rendered visible. Fig. 26 shows stained sporozoites.

The complete development of the gametocyst takes place when it is left dry on a slide, without any attempt at maintaining humidity. These conditions have, in fact, been found to be the most favourable for development. Gametocysts may be kept in water after the first 24 hours without harm, but will not develop if placed in water soon after excretion. It has been found that development is slower at lower temperatures, and an effort has been made to give average periods for the attainment of the various stages. The dehiscence period however, *i.e.* 15 days, was noted during the coldest month of the year at the Cape Peninsula. The time required for the complete development of the gametes is reduced to 24 hours if the cyst is maintained in a very warm room.

Possible, Functions of the Fusiform Male.

In a concluding summary of the likely functions of the infertile males Léger states: "I readily regard them as exciting elements, mechanical and perhaps even physiological; mechanical because their lively movements must contribute powerfully to the mingling of the fertile gametes, and physiological in secreting a substance which, as we have already said, would act on the female elements, inciting them to detach themselves in order to fall into the copularium." Although it is true that the fusiform males are endowed with considerable powers of movement, so also are the pear-shaped type, and these latter do not appear to need assistance in order to mix freely with the females. Doubt is thrown on the second suggestion

(that they might secrete a substance which stimulates the females to become free) by the previously described instance in which the females became detached after the death of the male gametocyte. Although the females become free soon after the males, there does not appear to be any evidence that they are influenced by the males in this matter, unless it is by purely mechanical effect.

The nucleus of the fusiform male is richer in chromatin than that of the pear-shaped type or the female gamete. It is similar in appearance to the residual concentrations of chromatin which lie behind the immature gametes in certain areas of the cyst. It appears possible, therefore, that while the residual chromatin concentrations of the female gametocyte fail to gather cytoplasm, those of the male continue development until full gamete formation of the fusiform type is attained. In this event it is obvious that, having an excess of chromatin, the latter would be incapable of fertilizing the female.

A possible function of the fusiform males is to promote movement of the non-motile zgyotes, thus assisting in their adhesion together in chains.

If they are in reality infertile—and careful observation tends to confirm this—they cannot properly be referred to as "infertile males" or "fusiform males" since they are not gametes in the strict sense of the term. In the absence of more suitable terminology these names have been used in the present paper.

Discussion.

The described gregarine qualifies for inclusion in the family Stylocephalidae (Ellis, 1912) in all essential characteristics. These are as follows: Gametocytes solitary before encystment, ovoid nucleus, development of pseudocyst, sporocysts black or brown in chains. It also possesses the following characteristics which qualify it for inclusion in the genus *Stylocephalus* (Ellis, 1912). The epimerite has a dilated papilla at the end of a long slender neck. The cyst is covered with elevations or "bosses". The gametogony is anisogamous, there is dimorphism of the male gametes, and the sporocysts are "purse-shaped".

The following five species of the genus *Stylocephalus* (syn. *Stylorhynchus*, Stein) are found in the Coleoptera:—

S. longicollis (Stein, 1848);
S. oblongatus (Hammerschmidt, 1838);
S. brevirostris (Kölliker, 1848);
S. gladiator (Blanchard, 1905);
S. giganteus (Ellis, 1912).

It has not been found possible to study the original papers; but the specific definitions given by Watson (1916) indicate that only *S. longicollis*

and *S. oblongatus* have been described in sufficient detail to permit of comparison, and neither of them agrees entirely with the gregarine described. The epimerite of *S. longicollis* possesses a longer trunk-like neck, while the deutormerite of *S. oblongatus* is almost cylindrical, tapering only slightly from the middle. It also has a protomerite-deutomerite ratio of 1 : 6 to 1 : 8 as against a minimum ratio of 1 : 35 in the present species. A further distinction is that in both *S. longicollis* and *S. oblongatus* the nuclei of the gametes are visible in the living state. The specific name *ingeri* is therefore proposed.

Summary and Conclusions.

1. A cephaline gregarine of the genus *Stylocephalus* found in the gut of the beetle *Gonocephalum arenarium* is described.
2. The young trophozoites adhere to the cells of the mid-gut, where they cause intercellular concavities.
3. The epimerite is spindle-shaped with a swelling at the free extremity.
4. The mature gametocytes encyst in pairs without previous association. The cyst-wall is covered with minute elevations.
5. The gametes formed on one associant are motile and possess flagellum-like organelles. Those developed by the other are immotile.
6. There is dimorphism among the motile (male) gametes: one type being apparently infertile.
7. Copulation takes place between the gametes, and zygotes result which later become attached in the form of chains.
8. The sporocysts are "purse-shaped", eight sporozoites being developed within each.
9. A pseudocyst is formed, and dehiscence is by disintegration of the gametocyst wall.
10. Possible functions of the infertile male gametes are discussed.
11. The specific name *ingeri* is proposed.

Acknowledgments.

Grateful acknowledgment is made for most invaluable advice and assistance from Dr. Andrew Robertson (lately Lecturer, Department of Protozoology, London School of Hygiene and Tropical Medicine), and for many helpful suggestions from Dr. H. Sandon, Department of Zoology, University of Cape Town. The insect host was identified by Dr. Albert Hesse, Entomologist to the South African Museum, Cape Town, who also generously contributed much other help.

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SOME REMARKS ON THE BIOLOGY OF REPRODUCTION IN THE FEMALE OF *ELEPHANTULUS*, THE HOLY ANIMAL OF SET.

By C. J. van der Horst, F.R.S.S.A., University of the Witwatersrand.

(With seven Text-figures.)

(Read June 20, 1945.)

Introduction.

During the last few years a good many articles have appeared dealing with the reproductive process of various small mammals. Most of these animals are rodents, which is not surprising, considering their great number of species, their economic importance, and the rather easy access to the extensive material necessary for this purpose. Deanesly and Parkes (1933) reported on the œstrus cycle of the Grey Squirrel; Brambell and Rowlands (1936) on the Bank Vole; Brambell (1944) on the Wild Rabbit. Some other papers deal with the more interesting insectivores, as Brambell and Hall (1937) on the reproduction of the Lesser Shrew, Brambell (1935) on the Common Shrew; Pearson (1944) on the North American Shrew *Blarina brevicauda*, and Deanesly (1934) on the Hedgehog. Further, there is Matthew's paper (1937) on the female sexual cycle of the Horse-shoe Bats.

For years a large amount of material of the South African Elephant Shrew (*Elephantulus myurus jamesoni*) has been collected. The primary object of the collecting was the study of the early embryology, but besides this several aspects of the morphology and physiology of the reproductive organs of this interesting animal could also be investigated, and several other problems are still waiting to be dealt with. In addition during these years a number of facts relating to the biological aspect of the sexual life of this remarkable animal have been accumulated, and it seems reasonable to submit these observations in the present paper.

Material and Methods.

Of the five genera of elephant shrews or Macroscelidæ: Elephantulus, Macroscelides, Nasilio, Petrodromus, and Rhynchocyon, the first-named has by far the greater number of different species and the widest distribution. Species of *Elephantulus* are found all over Africa from the Cape to Algeria. In the neighbourhood of Johannesburg, as on the whole highveld

of the Transvaal, *Elephantulus myurus jamesoni* is a rather common animal in suitable localities, yet it is not easy to see and even more difficult to catch. It can be expected at any place where large loose stones and boulders provide it with shelter in horizontal fissures and crevices. Being diurnal in habit it likes to sit in the sun on top of the stones, but as soon as anything suspicious approaches it dashes off to hide itself underneath the stones. The animal's eyesight seems to be good, so that it usually observes one approaching before one is aware of its presence. Sometimes one can succeed in catching an animal by turning over the stones; mostly, however, the stones are too large. And even if the stone is not too large the animal mostly succeeds in escaping underneath the next boulder. This makes collecting elephant shrews sometimes a fascinating but mostly a disappointing sport, taking up much time. The best method of catching elephant shrews proved to be with the help of a long net of about ½-inch mesh. If an animal is seen dashing under a stone, this stone is surrounded by the net, held by a few helpers, and then the animal is chased from underneath the stone with a piece of wire and caught in the net. In this way the many hundreds of animals necessary for our work were caught alive, so that they could be fixed immediately after being killed.

Nearly all our animals were collected near Bronkhorstspruit, a village about 40 miles east of Pretoria, where our collector lives. Mostly they were killed immediately after capture, sometimes they were sent to Johannesburg alive. This journey, taking nearly a day, has some disadvantages. In the first place *Elephantulus* is a delicate animal, and quite a number are hurt when caught and die during the journey. In the second place the animal has pronounced cannibalistic tendencies and a number are lost in this way. Thirdly, when *Elephantulus* is molested in any way it readily commits abortion. We have in our collection a great many post-abortion uteri; although these uteri with the ovaries show some interesting phenomena, it should have saved us a lot of trouble if we had found the embryos in their proper place.

In nature the usual food of *Elephantulus* seems to consist of grasshoppers and other insects. In the laboratory we kept them alive on meat and succeeded in keeping them for up to six months. In nature the duration of life seems to be about one year, and as the animals when caught were full-grown their meat diet in the laboratory is apparently not harmful to them.

Yet they are not good laboratory animals, for, as they need plenty of room to run about, only a few can be put in a cage together. Besides, even if provided with plenty of grasshoppers the animals go invariably into anœstrus in captivity, even when caught at the beginning of their season. Deanesly (1934) met with the same difficulty in hedgehogs. Therefore all

observations mentioned in this paper were made on animals caught in the wild and killed soon after capture. By the study of their ovaries and uteri in serial sections quite a lot can be learned about their sex life. As the size of the animal is somewhat between an ordinary rat and a mouse, the sex organs are small enough for sectioning the ovary with one complete horn of the uterus in a great many specimens. By a careful study of several hundreds of serial sections gradually a certain amount of experience was gained, so that from the aspect of the ovary in combination with the date of capture nearly the whole history of the sexual life of the animal could be given. The absolute age of the animals was of course unknown, but from the appearance of the ovary in sections and the number of primary oocytes in the ovary a fairly accurate estimate could be made of the relative age. Thus a young animal with only one or at most two layers of granulosa cells around the egg cells was given the relative age by way of comparison of 10. The ovaries are then crowded with small oogonia. Fifteen is the age of a young animal in the ovary of which many multilayered follicles appear, and the first batch of follicles begins to form fluid between the granulosa cells. Animals at or near the first ovulation are placed in age-group 20. This does not seem to be correct, but as ageing for this animal is rapid and its life short, this discrepancy could not be avoided. It could also be said that a sexually mature animal comes in age-group 20 and then the comparison is more to the point. Animals left with only a very few eggs in the ovary were placed in age-group 45. In these extremes no mistake can be made in the estimation, but in the middle it becomes more difficult. By the growth of a great number of Graafian follicles and by the presence of the numerous corpora lutea the size of the ovary is increased considerably and therefore the primary oocytes are more widely distributed and their number in one section is smaller, so that one is inclined to over-estimate the age of the animal. Yet an animal of an age of 20 to 25 can easily be recognised from one of 35 to 40. In between 20 and 45 an estimate was made always in a plural of 5; that was the nearest approach that could be made, and even so for the middle age-group it is more or less a guess. But by the study of a few hundred ovaries enough experience was gained for a reliable guess. Moreover, Dr. J. Gillman and myself estimated the age of each animal independently, and on comparing notes it was found that there was always a complete or anyhow a very near correspondence between our estimates.

To give a concrete example of what can be deducted of a study of the ovary and uterus, the life-history of one animal, the ovary and uterus of which form series 498, will be given here. The animal was captured and killed on 4th August 1941. The ovary showed a very occasional primary oocyte and a few follicles with one or two layers of granulosa cells, but not a

single multilayered follicle. Corpora albicantia were present in considerable number. The cortical layer of the ovary was very thick and dense. All this shows that the ovary was practically exhausted, so that the animal comes in the age-group 45. The uterus, on the other hand, had a high epithelium, straight glands with a fair number of mitotic divisions in the cells and the endometrium showed a general œdema. These are definite indications that the animal was going into œstrus when it was caught and killed. As there were no Graafian follicles in the ovary, there was therefore no correspondence between the ovary and the uterine horn, which, otherwise, is always the case. So the other ovary and uterine horn were sectioned too, they form series 534. This horn shows the same picture as that of series 498 and the ovary is also that of an old animal. But in this ovary a fair amount of ripening follicles in the process of fluid formation were found; evidently the last crop of ripe follicles that the animal could produce, as only a very few smaller follicles were left. These ripening follicles explain the œstrogenic appearance of the uterus. Now with the experience gained from the study of several hundreds of animals the following life-history of this particular animal can be deducted with a fair amount of certainty.

The animal was born in January 1940 or anyhow at the end of the reproductive season of the summer 1939–1940. Having grown up it went straight into anœstrus in the autumn of 1940, *i.e.* in February as a virgin. It came into œstrus at the end of July or beginning of August of 1940, and became pregnant three times during the season 1940, producing six young ones in all. Soon after the third parturition it must have gone into anœstrus again in January 1941 and it survived its second winter, which is of rare occurrence. The few follicles left in the one ovary started ripening at the end of July 1941 and were sufficient to produce the œstrogenic appearance of the uterus. Here ends the story of this animal on 4th August 1941. Had it lived longer it would most likely have copulated in a few days time. We have another series of an ovary and uterus of a similar old animal in which sperms were found in the uterus, but unfortunately the date of capture of this animal is not known. In case the eggs liberated from the ovary had been fertilized the animal might have become pregnant for the fourth time, but as no more follicles were left in the ovaries this pregnancy would not have been carried on till parturition; most likely the animal would have died from old age in the early stages of her last pregnancy.

During previous years some knowledge was gained about the dates of the productive period of *Elephantulus*, but as the collecting had been done rather haphazardly on account of our ignorance of the breeding habits of *Elephantulus*, more exact data about several questions were lacking. Therefore it was decided to collect a number of animals, about 10 each week, during the whole season 1941–1942, and although a few weeks were

missed a fairly accurate account of the reproduction of *Elephantulus myurus jamesoni* can be given. It must be taken into account that these animals were collected at Bronkhorstspruit. This place lies at a considerable lower altitude than Johannesburg, so that the average winter temperature is higher there. Therefore, it is possible that near Johannesburg the reproductive season starts a few weeks later than in the vicinity of Bronkhorstspruit. In each of these animals one ovary was sectioned, mostly with one uterine horn. Only when the uterus contained embryos large enough to be measured macroscopically was the uterus not sectioned.

Anœstrus.

The ovary of an animal in anœstrus can easily be recognised by the total absence of any activity. During the months of the anœstrus period no change whatsoever takes place in the ovary. In an animal that has been pregnant and given birth near the end of the previous season the corpora albicantia do not undergo any alteration; their gradual involution will set in only when the animal becomes pregnant again in the next season, and they will disappear at about the same stage of the pregnancy as when a first pregnancy of the season is immediately succeeded by a second. In the whole of the ovary there are no mitotic divisions. Follicles are numerous, from small ones with one layer of granulosa cells up to multilayered follicles, but none of these follicles show any sign of the formation of fluid or of the differentiation of the corona radiata. The presence or absence of corpora albicantia indicates unambiguously whether the animal has been pregnant before or whether it has entered the anœstrus period as a virgin. The number of primary oocytes is another indication of this. But in both classes of animals the ovary is small because of the absence of ripe Graafian follicles and corpora lutea.

The picture shown by the uterus during anœstrus is also very characteristic. Except for the blood-vessels no difference can be seen between the uterus of a virgin or of a parous animal, as was found also by Brambell (1935) in *Sorex*. The uterus is very small and of a characteristic cross-section (fig. 1). Its vertical diameter, *i.e.* from the mesometrial to the anti-mesometrial end, is about twice its horizontal diameter; *e.g.* in a virgin it measures $1{\cdot}62 \times 0{\cdot}80$ mm., and in some parous animal $1{\cdot}70 \times 0{\cdot}78$. These measurements were of course taken at the place of the greatest diameter of the uterus, where during pregnancy the embryo will settle about 1 to 2 mm. in front of the junction of the uterine horns to the median uterus. In cross-section the uterus is more rounded at the mesometrial side and more pointed anti-mesometrically. The stroma is very dense and the glands irregularly coiled. As in *Sorex* the uterine epithelium is thin and composed

of a single layer of cubical cells (fig. 2). The thickness of the epithelium in the parous animal mentioned above is 8·6 μ. The nuclei are small and pycnotic, yet they fill nearly the whole cell except that the nucleus is round

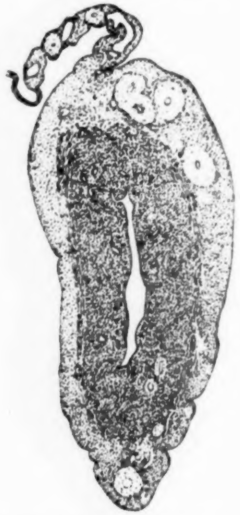

Fig. 1.—Cross-section of the uterus of a parous animal during anœstrus. × 40.

Fig. 2.—Uterine epithelium during anœstrus. × 1000.

and the cell cuboidal. Mitoses are completely absent both in the glands and the uterine epithelium. The uterine lumen is narrow and filled by a mucous plug.

Coming out of Anœstrus.

Elephantulus myurus jamesoni comes out of anœstrus in the middle of July, that is in the latter half of the short South African winter.

Of the twelve animals collected on 21st and 23rd of July 1941, only one was still completely in anœstrus, all the others show already the changes indicating that the animal is coming out of anœstrus in a more or less advanced degree, and one animal is already nearly in full œstrus. So this batch of twelve animals already shows that the process of coming into œstrus is far from being simultaneous in all animals. This is accentuated if animals collected at later dates are also considered. So of the four animals collected on 2nd August 1941, one is still almost in anœstrus, whereas on 12th August a pregnant animal with an embryo of 11 mm. was collected.

No difference in the time of coming out of anœstrus can be observed

between virgin and parous animals. The animal in anœstrus on 21st July is parous, and that nearly in œstrus on the same date is a virgin. On the other hand, the animal still in anœstrus on 2nd August is a virgin, and that with an 11 mm. embryo on 12th August had been pregnant in the previous season.

The phenomenon of coming out of anœstrus manifests itself in the ovary by the appearance of a few mitotic figures in the stratum granulosum. The number of mitotic figures is rather small. In a single section, passing through the centre of the follicle, four of them can be counted at the most, more often there are only one or two. Gradually by the multiplication of granulosa cells the number of multilayered follicles increases. All these cells are still of the same nature. The real ripening of the follicles in preparation for ovulation is initiated by the differentiation of the corona radiata cells from the rest of the granulosa cells. The corona cells at first, like all granulosa cells, are small, polygonal, and closely packed. Now they become larger, elongated, and the nuclei are arranged in a regular row in the peripheral part of cells, away from the egg. Shortly afterwards small droplets of fluid appear between the corona and the granulosa cells. These droplets increase in size and become confluent. Finally the ripe Graafian follicles are formed and the process of ovulation sets in (van der Horst and Gillman, 1940).

The first visible change in the uterus is a thickening of the uterine epithelium, which during anœstrus consists of low cuboidal cells, its thickness was measured as $8{\cdot}6\ \mu$. This thickening of the uterine epithelium starts very early; it may be the only indication, and added to that an obvious one, that the animal comes out of anœstrus. In the animal collected on 2nd August 1941 that does not show any ovarian activity, the uterine epithelium has already increased in thickness to $14\ \mu$. Finally at the time of œstrus the epithelium reaches a thickness of $30\ \mu$ and over (fig. 3). It consists then of well-defined large columnar cells. The nuclei of those elongated cells are, however, lying in a single row in the basal part of the cells. This is an important characteristic of the epithelium of the œstrous uterus. During the menstrual cycle and in early pregnancy a thick epithelium also occurs in the uterus. But then the nuclei are situated in more layers in accordance with the narrowness of the cells.

A second indication of uterine activity is a loosening up of the stroma by accumulation of fluid. This sets in much later than the thickening of the epithelium or the ripening of the follicles. The stroma is often still dense when the epithelium has already reached a thickness of 20 to $25\ \mu$. Finally this process results in the highly œdematous stroma seen in the uterus at the time of œstrus (fig. 4). The œdema is restricted to the posterior part of the uterus horns, a few millimeters in length, where im-

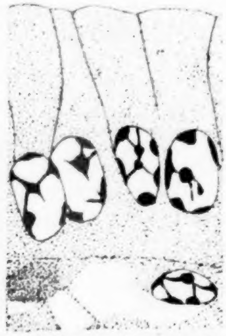

FIG. 3.—Uterine epithelium at the time of œstrus. × 1000.

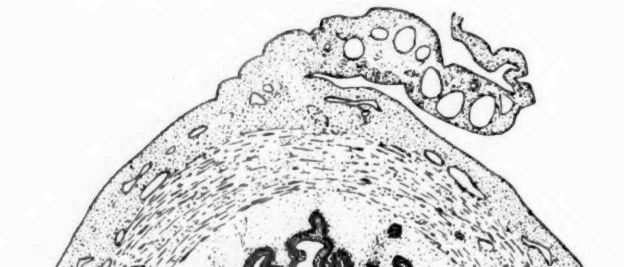

FIG. 4.—Cross-section of the uterus of a young animal in œstrus. × 40.

plantation will take place later on. This œstrogenic œdema is strikingly different from the œdema seen in the uterus at the same level shortly before implantation, and also the œdema appearing prior to menstruation. These latter œdemata are strictly confined to the mesometrial side of the uterus where implantation takes place or where the polyp of menstruation grows out, whereas the anti-mesometrial stroma remains dense. The œstrogenic œdema, on the other hand, affects the uterus all round, not the slightest difference in intensity can be noticed between the mesometrial and the anti-mesometrial side of the uterus.

Concomitant with or even prior to the loosening up of the stroma a change takes place in the uterine glands. During anœstrus these glands are very narrow and coiled and in the dark, dense stroma they are hardly perceptible. Already before any reaction in the stroma can be seen some mitotic figures may be noticed in the epithelium of the glands, and at the same time the lumen of the glands widens slightly. When the œdema appears in the stroma the glands become more and more straight, resulting finally in the very obvious, wide and straight glands in the œstrogenic uterus.

These changes in the stroma and the glands affect the appearance of the uterus in cross-section. During anœstrus the uterus is compressed and the lumen a narrow slit. But now the uterus becomes more circular in cross-section and the lumen widens out accordingly. From the diameter of 1·7 by 0·78 mm. during anœstrus the uterus swells up and reaches a diameter of 2·64 by 2·32 mm. at the time of œstrus. This swelling of the uterus again is confined to the posterior part of the uterine horns.

How long does this whole process of coming out of anœstrus and going into œstrus take? As it is not possible to follow the process in one particular specimen the exact length of time cannot be given. Only an approximation can be made by comparing as many animals as possible. And here again a difficulty arises as the number of animals of which the uteri and ovaries were sectioned is for obvious reasons small. The number is anyhow too small for any statistical approach to the question. It only allows us to make an estimate. Of the twelve animals killed on 21st and 23rd July, one was still in anœstrus, one nearly in œstrus and well advanced above the rest, which all show more or less marked indications of coming out of anœstrus. With a fair amount of certainty it can be said therefore that the process of coming out of anœstrus starts as a rule between 15th and 20th July. Of the five animals killed on 29th July 1941, two have copulated and are in œstrus, the other three are coming out of anœstrus. Eleven animals were killed on 2nd and 4th August 1941. Of these one is still nearly in anœstrus, two are coming into œstrus, and eight are coming out of anœstrus. A definite change is seen on 12th August; of eight animals,

two are pregnant, one of them with an 11-mm. embryo, four are coming into œstrus, and only two are still coming out of anœstrus. All five animals killed on 13th August were in early pregnancy. On the other hand, one animal out of ten was found to be still ovulating on 4th September, but this can be regarded as exceptionally late. From this it may be assumed that *Elephantulus* as a rule is in œstrus about the 10th of August. Therefore the length of the whole process from anœstrus to œstrus may be estimated as about three weeks.

Deanesly (1934) found that almost all hedgehogs investigated by her pass through three to five sterile cycles previous to pregnancy at the beginning of the season. This results in the presence of a good many corpora lutea in the ovary. In *Elephantulus* repeated ovulation never occurs at the beginning of the season. Invariably it was found that the numerous eggs liberated at the first ovulation were fertilised, or at least the majority of them. The number of corpora lutea in the ovary always corresponds to the number of eggs liberated at one ovulation, and this number is larger than in any other mammal (van der Horst and Gillman, 1941 *a*). Only at the end of the season, previous to going into anœstrus, repeated ovulation may occur in *Elephantulus*, but this phenomenon bears a character apparently quite different from that described by Deanesly in the hedgehog at the beginning of the season (van der Horst and Gillman, 1941 *b*).

Although the first ovulation of the season always results in pregnancy, ovulation in *Elephantulus* is spontaneous and not caused by copulation, as in several other mammals. The shrew *Blarina* needs even many copulations to cause ovulation (Pearson, 1944). Except for one rather doubtful case of a young animal with a first crop of ripening follicles, sperms were never found in the uterus until after ovulation. Besides, sterile ovulations are a common phenomenon in *Elephantulus* at the end of the season; at the beginning of the season a sterile ovulation was never observed.

Gestation Period.

Our material also provides us with some indications as to the length of the period of gestation. As seen above, we may take the 10th of August as the day when *Elephantulus* is in œstrus and when fertilisation takes place, although this may and often does occur before that date.

The first postpartum animal was collected on 26th September. Another of the six animals collected on that date was near parturition; the length of the fœtus was 35·5 mm. and birth takes place when the length is about 40 mm. Five animals were collected on 4th October; of these one was gravid for the second time as shown by the presence of corpora albicantia

in the ovaries. The other four had embryos with a length of 7·4 mm., 25 mm., 34 and 35 mm., so two of them are near parturition. Of the six animals collected on 7th Otcober, three were pregnant for the second time, and the other three had embryos 18·5 mm., 29 and 36 mm. long. On the 14th October five animals were found to be pregnant for the second time, and one had a fœtus of 28·6 mm. At the same date a young animal with a body-length of 6·3 cm. was caught; the body-length of the full-grown animal is 12 cm. On 15th October 1943 two pregnant and lactating females were received, as well as a young animal with a body-length of 8·5 cm. Further, a litter was born in captivity on 28th September 1943 from a mother captured a few weeks earlier. From these data, although they are scanty, it may be deduced with a fair amount of certainty that the gestation period lasts nearly eight weeks. This is a very long time for a mammal of the size of *Elephantulus*. According to Deanesly (1934) the gestation period of the much larger hedgehog is about one month. But it has to be remembered that the young ones are born in a very advanced state, they walk about at once after birth.

Number of Pregnancies in One Season.

About two days after parturition postpartum ovulation takes place. Nearly always at the end of September or the beginning of October the animal is fertilised and the second pregnancy sets in; a lactation anœstrus does not occur in *Elephantulus*. On 4th October one out of five animals was found in early pregnancy and with corpora albicantia of the previous pregnancy. The same condition was found in three out of six animals collected on 7th October, and with five out of six animals on 14th October. So the birth of the second litter may be expected by the end of November or beginning of December. This is confirmed by the seven animals collected on 25th November, three of which were young animals, another three had embryos with a length of 28·3 mm., 30 and 39 mm., so all nearing parturition. The seventh animal is somewhat doubtful, it is pregnant in a very early stage with a four-celled blastula, so it might be the second or the third pregnancy. However, the age of the animal as estimated from the appearance of the ovary, relative age of 30, shows that it is the animal's second pregnancy.

The second parturition at the end of November or beginning of December seems to be followed immediately by a third pregnancy. However, the picture as presented by our material becomes more and more obscured and the conclusions that can be drawn less and less reliable. Some of the young animals born a few weeks earlier are becoming adult and pregnant now, and as every week about the same number of animals were caught the

older animals in our catches become less numerous. Moreover, already at the beginning of the season there may be a variation of a few weeks in the coming out of anœstrus between different animals, and for various reasons the animals may become more and more erratic towards the end of the season. Finally by some accident no animals were collected during the first half of December 1941. On 18th December one older animal was collected in early pregnancy; it is likely that that was the third pregnancy of the season. Three other older animals, killed the same day, had embryos with a length of 10 mm., 13·7 and 19 mm., in these cases the position is more doubtful. None of the animals collected on 29th December give a clear indication in this respect. In January the position becomes even more difficult because young animals of the same season may now be in their second pregnancy, so the mere presence of corpora albicantia in the ovary is of no help. Only the few animals that are really old, judging from the small number of oogonia or follicles left in the ovary, can be taken into consideration, they fall in the age-group of 40 to 45. On 6th January one such animal was collected with an embryo of 11 mm., on 15th January one animal with an embryo between 6 and 7 mm.; on 12th February 1942 one animal was collected with an embryo of 12·5 mm. and another animal had just given birth. Besides we have two older animals, collected on 14th December 1937, one had an embryo with 21 and the other with 40 somites, so both animals are in rather early pregnancy. Altogether in our collection of sectioned material we have seven animals indicating that a third pregnancy occurs. Other factors such as the duration of life and the rate of fertility give support to the conclusion that three pregnancies occur during the season.

Age of Puberty.

Elephantulus myurus jamesoni has always twins. When the animal is born its body length is about 5 cm. or a little more. Just before birth the crown-rump length of the fœtus is about 4 cm. Immediately after birth the young can walk round and soon they collect their own food. As previously mentioned, the first parturition of the season takes place at the end of September or beginning of October, and for obvious reasons only the animals then born can be taken into account for the present purpose. On 14th October a young animal with a body-length of 63 mm. was collected. On 7th November three young but full-grown animals were collected, one was still prepubertal, the second ovulating for the first time, and the third was in very early pregnancy. This tends to show that the animals are sexually mature in five or at most six weeks after birth. The hedgehog may become sexually mature in the season of its birth but mating is extremely unlikely (Deanesly, 1934).

Total Number of Pregnancies during Life.

From the estimated relative age we may come to the absolute age and the duration of life of *Elephantulus*. Of the thirty-six animals collected between 21st July and 12th August 1941, fourteen are young animals that have not been pregnant before. These figures, fourteen out of thirty-six animals, are sufficient indication that *Elephantulus myurus jamesoni* has three pregnancies during its life. By the end of the first pregnancy of the season on 26th September we got three animals of age-group 25, two of 35, and one of 40; on 4th October one of 30, four of 35, one of 40. This shows that after one pregnancy the animals come in the age-groups of 25 or 30. Therefore, animals of the age-group 35 can be expected to have had two pregnancies, and after the third pregnancy the animals come in the age-group 40 or 45. We may, therefore, conclude that *Elephantulus* normally has only three pregnancies during its life. Animals of 45 may become pregnant, this undoubtedly is a fourth pregnancy; of our twelve animals of this age-group four are pregnant, but all four in a very early stage, and there are reasons for expecting that this pregnancy cannot successfully be concluded. Pregnancy is accompanied by the formation of many cystic follicles in the ovary, and this seems to be an indispensable part of the process (van der Horst and Gillman, 1945). But these animals of age-group 45 have no follicles left in the ovary and, therefore, they will probably die during their pregnancy.

There are forty-five animals of the age-group 40 in our collection. Most of these are pregnant, which is not surprising as for the purpose of embryological investigation pregnant animals were selected for sectioning. The question, however, is whether this is a third or a fourth pregnancy. Now most pregnant animals are in the early stages of pregnancy, which again is not surprising. For the earlier stages one is to some extent dependent on good luck to get a complete series of embryological stages and, therefore, one has to section many uteri. The older stages, of course, can be selected before sectioning. The age of the mother is of no account in this selection as it can be determined only when the material is sectioned. The four animals of the age-group 40, in a more advanced stage of pregnancy, had embryos of 11, 12·5, 18·2, and 18·5 mm. in length. Here we are dealing without doubt with a third pregnancy. But it is also most likely that the animals of this group in early pregnancy are only pregnant for the third time, although it is somewhat belated. These animals may have lost a number of oogonia during one or two menstruations or by an interrupted pregnancy before going into anœstrus. Then they are older at the time of the third pregnancy than other animals that directly upon reaching sexual maturity have gone into anœstrus.

These pregnant animals of group 40 can be expected to bring their pregnancy to a successful end. So it can be accepted that normally an animal has three pregnancies during its lifetime. They may all occur in one and the same season, or they may be divided over two seasons.

Fertility-Rate.

An animal being gravid three times in its life and giving birth to twins each time would produce a total of six offspring. So if everything goes well it can be expected that one female produces a total offspring of six in her lifetime as well as in one season. In favourable circumstances the members of the first litter of the season would be sexually mature in five or six weeks and then produce two sets of grandchildren. The second litter could give birth to one set of grandchildren in the same season. So the total offspring that would theoretically be possible in one season amounts to not more than twelve.

However, if six is the expected number of children in one pair of animals, the question arises as to what the actual number may be. In order to find this we have to take the death-rate into account. As previously stated, the relative age of the sexually mature animals was estimated from the appearance of the ovary. In this way the animals could be placed into age-groups of from 20 to 45 with a difference of 5 between each successive age-group; a greater accuracy could not be reached except between 40 and 45 when only a few eggs are left in the ovary. The 508 animals, the ovaries of which have been studied, were divided over the different age-groups. When the intermediate groups, most numerous between 20 and 25 and again between 40 and 45, are apportioned equally between the two adjoining groups, the distribution is as follows:—

Age-group.	Number of Animals.
20	116
25	117
30	116
35	80
40	64
45	15

These animals were collected at random in the wild. Also for sectioning the material no selection as to the age can be made because the age can only be estimated after the ovary has been sectioned. In this respect, therefore, the selection of the material is unbiassed. So it can be assumed that the material gives a fair sample of the age distribution of the original population at the place where the animals were collected.

It has to be realised, however, that these age-groups do not give a classification by a calendar age, but being based on the appearance of the

ovary they represent groups of fertility age or sexual age. An animal born in January goes into anœstrus as a virgin and gives birth to her first twins at the end of September when she is about eight months old. Another animal born at the end of September becomes adult and pregnant at the beginning of November and gives birth at the beginning of January when it is hardly three months old. Yet, as during the six months of anœstrus no change takes place in the ovary, their ovaries show the same picture and both animals are classified in the same age-group. But for the present purpose of figuring out the fertility-rate the absolute age of the animals is of no consequence.

It has been stated before that females after one completed pregnancy come from age-group 20 to groups 25 or 30. Moreover, we have seen that the animals have three pregnancies during their reproductive life, *i.e.* between the age-groups 20 and 45. Therefore, for the present purpose it is appropriate to reclassify our animals into age-groups 20, 27½, 35, and 42½. This would show the following distribution:—

Age-group.	Number of Animals.
20	155
27½	156
35	138
42½	58

From these figures, as well as from those of the age-group 20, 25, etc., it appears that all females that reach maturity have one litter, that there is a small drop in the number completing a second pregnancy and a big drop in the number completing a third pregnancy. So if we start with 156 females they will all have two offspring, 138 of them will produce a second litter, and 58 a third. During their life it can therefore be expected that the 156 females give birth to $2 \times 156 + 2 \times 138 + 2 \times 58 = 704$ young. The actual number of offspring from each female that reaches maturity or from two animals, one male and one female, is therefore 4·5.

It follows, that if a stationary population is assumed the "infant mortality" would be 2·5 out of 4·5 or about 55 per cent. Both these figures, the "fertility-rate" and the "infant mortality rate," seem to be exceedingly low for a wild animal.

Duration of Life.

The remarkable low rate of reproduction makes it probable that at least some animals should reach the maximum age allotted to *Elephantulus myurus jamesoni* and die a natural death of old age. In all our material, however, not a single animal was encountered of an age-group above 45, *i.e.* in which the ovaries were completely exhausted. From this it may be

concluded that *Elephantulus* cannot live beyond the completion of its sexual life. The relative age of 45 is its maximum age.

From what has been said before, it is now not difficult to compute the real maximum age of *Elephantulus*. The growth of the animal from birth to sexual maturity extends over five to six weeks. Every full-grown animal, provided it does not die prematurely, passes through one reproductive period, from the middle of July to the middle of January, in its lifetime and also goes through one period of anœstrus which equally extends over six months. So the natural duration of the life of *Elephantulus* will be slightly over 13 months. Only in exceptional circumstances its life may be prolonged by a second period of anœstrus of six months. When at the end of the reproductive season, during which the animal has given birth to three litters, its ovary is not completely exhausted but still retains a few follicles, it may be fortunate enough to survive a second period of anœstrus and reach an age of 19 months. The few follicles left in the ovary are then sufficient to bring about a new period of œstrus and such an old female may be fertilized and become pregnant again. But the few follicles left after ovulation are only sufficient for the first stages of pregnancy; with their exhaustion the animal will die its natural death. In all our material an old animal was never found in an advanced state of pregnancy. Therefore, the natural life span of *Elephantulus* is determined by its sexual life or by its capacity for further reproduction. An increase of the duration of life above the reproductive age is impossible, and the problem of a general ageing of the population by an increasing number of old individuals can never arise in *Elephantulus*.

Thilenius (1900) gives good reasons to show that *Elephantulus* (the North African species belongs to this genus and not to *Macroscelides*) is the holy animal of the old Egyptian god Set. Being a rather small and secretive animal, *Elephantulus* is unknown outside zoological circles, it is therefore no wonder that the Egyptologists cannot assign the characteristic head of Set to any particular animal. According to the *Encyclopædia Brittanica* the donkey and the pig dispute the honour of giving a head to god Set. Brockhaus is of the opinion that the holy animal is some remarkable, now extinct quadruped, and the *Enciclopedia Italiana* refers Set's head even to the Okapi. Wiedemann says that "this head bears some resemblance to a camel's head and is the same as that of the long-tailed fabulous beast, the supposed incarnation of Set". Although the little figure depicting this fabulous beast is very schematic, not only the head and the long tail but also the posture of the animal is like that of *Elephantulus* (fig. 5). The animal heads of the various Egyptian gods, even when drawn in a few

simple lines, are so characteristic that no doubt as to their identity can be left (fig. 6). Therefore, the uncertainty in respect to the head of Set can

FIG. 5.—Figure of the long-tailed fabulous beast, the supposed incarnation of Set.

FIG. 6.—The figure of Set.

only be ascribed to a well understandable ignorance of the animal which it represents. That Set was the god of the desert and drought and that he

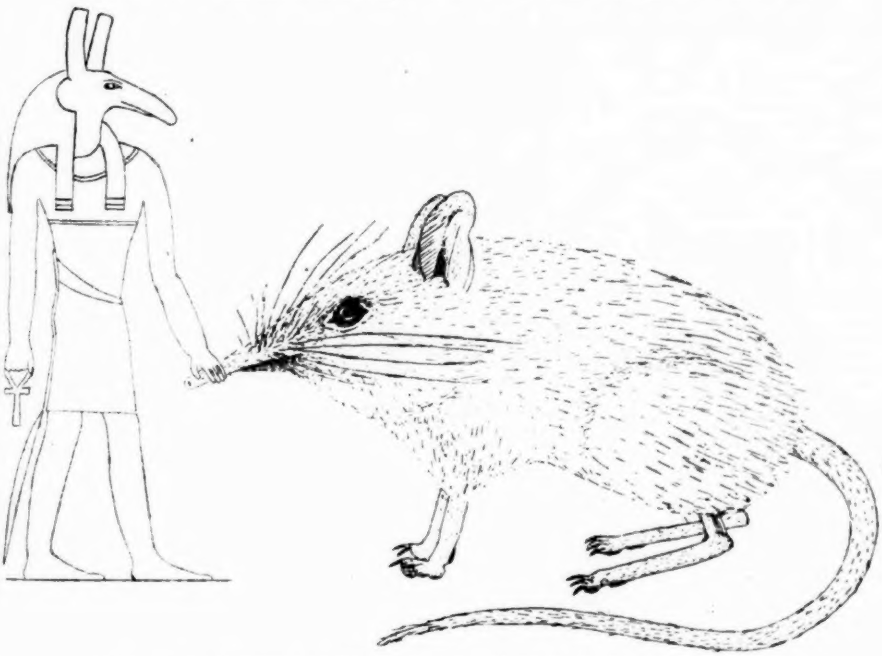

FIG. 7.—The Egyptian god Set with his holy animal *Elephantulus*, drawn from a living specimen of *E. myurus jamesoni* (Chubb). × $\frac{3}{4}$.

was killed by the hawk-headed Horus also plead for the identification of this holy animal with *Elephantulus*. But that Set and therefore *Elephantulus* should be the personification of Evil is not very acceptable, at least to me.

Anyhow, it is a long time ago since Set lived, and most likely the old Egyptians did not know much about the animal's embryology; they may have observed its cannibalistic tendencies, however.

Summary.

The changes taking place in the ovary and the uterus of *Elephantulus myurus jamesoni* during the transition from anœstrus into œstrus have been described. From the appearance of the ovary it was possible to divide the material, consisting of 508 specimens, into age-groups. The gestation period was estimated to last about 8 weeks. Three pregnancies were found to follow each other immediately during the breeding season of six months. Puberty is reached five weeks after birth. Three pregnancies, always of twins, may occur at most during the whole life of the animal. The maximum number of offspring therefore is six; however, taking the death-rate into account, the fertility-rate was found to be 4·5. The natural duration of life is just over 13 months.

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BLOOD STUDIES IN CHILDREN IN RELATION TO THEIR NUTRITIONAL STATUS.

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(With Three Text-figures.)

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CONTENTS.

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I. THE VALUE OF THE BLOOD HÆMOGLOBIN LEVEL AS AN INDEX OF NUTRITION IN SCHOOL CHILDREN.

Introduction.

There is a general consensus of opinion that the hæmoglobin level of the blood is adversely affected by malnutrition. The extensive researches of Whipple and Robscheit-Robbins (1930) on the relative value of different dietary factors in stimulating regeneration of hæmoglobin in dogs, rendered artificially anæmic by repeated bleeding, and the extensive researches on nutritional anæmia in rats from many centres, constitute a large body of evidence for such a conclusion.

In recent classifications of human anæmias one of the most important groups is that called the deficiency dyshæmopoietic anæmias. The dietary factors, absence of which from the diet is known to produce human anæmia, are iron, vitamin C, the extrinsic factor of Castle and possibly copper. It is therefore, not strange that the determination of the hæmoglobin concentration of the blood has been recommended as a test for human malnutrition in the absence of disease (Bigwood, 1939). MacFarlane and O'Brien *et al.* (1944) also make special mention of the present widespread adoption of the hæmoglobin level as an index of nutrition. To what extent it can truly be regarded as such is, however, not yet certain. There is not much recent work and the literature that there is is rather contradictory on this point.

Laugier, in a Publication of the League of Nations (1936), has given a

very comprehensive review of the literature between the years 1887 and 1935 on this point, a brief summary of which would be as follows:—

A few of the earlier workers were quite undecided as to the part played by undernutrition and felt that the hæmoglobin content of the blood may be influenced either one way or the other.

A small number of workers have remarked on the high, often even increased, levels of hæmoglobin sometimes encountered in badly nourished cases.

The more favoured opinion, however, seems to be that a state of undernourishment gives rise to a lowered hæmoglobin content of the blood. In addition to the numerous references (up to 1935) cited by Laugier in support of this statement, the findings of Davidson and Fullerton (1935), Stuart (1938), Linder and Massey (1939), and Napier and das Gupta (1940) should also be considered.

The Material: its Selection and Classification.

In view, however, of the conflicting and scanty nature of the literature it was decided to obtain some more information on this point by submitting the blood hæmoglobin readings of 525 carefully selected malnourished and 441 carefully selected normal children to a statistical analysis.

These children were selected from among a total of 1345 school children (8–16 years) of which the Cape Nutrition Survey (Brock and Latsky, 1942 and 1943) had made an intensive survey.

The Diseased Group.

On the basis of a clinical examination, supplemented chiefly by the sedimentation and Wassermann reactions of the blood and further laboratory investigations (where required), those children were first excluded from the survey who were judged to be showing evidence of such disease as might be expected to prevent satisfactory nutrition even though the diet be satisfactory. They were, therefore, rejected on the grounds that any malnutrition present might just as well be due to disease as to defective diet. In cases of doubt the full resources of the Groote Schuur Hospital diagnostic departments were used by referring the child to such department(s) for opinion.

The "Malnourished" and "Normal" Groups.

The remaining children were then divided into two groups, "malnourished" and "normal", the division being made primarily by assessment into the conventional four groups of the Dunfermline scale: excellent, normal, slightly subnormal (requiring supervision), and bad (requiring

treatment). Children falling into any of the two upper groups were looked upon as "normal" (healthy and of satisfactory nutrition), and those falling into the two lower groups were looked upon as "malnourished", *i.e.* those whose state of nutrition was judged to be unsatisfactory even in the absence of any evidence of disease such as might interfere with satisfactory nutrition.

This assessment was based chiefly on such external factors as general impression (harmonious effect), musculature, fat and subcutaneous tissue, thoracic defects, abdomen, shoulders, posture, etc. Two independent examiners agreed in most cases in their classification. Where there was disagreement, consideration was given to all the laboratory tests used in the Cape Nutrition Survey (Baumann and Brock, 1942; Brock and Latsky, 1942; Brock and Latsky, 1943; Linder and Latsky, 1942).

The tests (besides the routine Wassermann and blood sedimentation tests) included hæmoglobin readings, X-ray of one carpus for degree of skeletal development, vitamin C saturation test, and in selected cases determinations of the blood calcium, phosphorus, and phosphatase. These tests were mostly of an objective nature and concerned mostly with the detection of early indications of deficiency in such protective nutrients as vitamin C and certain mineral deficiencies such as calcium, phosphorus, and iron or features related to these.

It is this final classification into "normal" and "malnourished" groups which forms the foundation of this study; on it were based the blood studies comprising this and following papers.

The Use of Somatometric Indices.

Two physical indices, the A.C.H. and Tuxford (Franzen and Palmer, 1934; Tuxford, 1939), were employed, since they were supposed to have given very reliable results in past surveys (Jones, 1938).

From our own tests, however (Latsky, 1942), we now know that these indices must probably be looked upon rather as physical than nutritional indices; that they are obviously useless for the selection of malnourished children, and that they probably also depend on endocrine or hereditary factors which are under the control of influences other than just diet or state of nutrition. A typical example is the increase in skeletal stature and somatic growth as a result of endocrine influences at the stage of puberty, when anthropological factors may easily be confused with nutritional influences.

In justification it can, however, be said that the indices proved helpful to detect those individuals whose physical development was really below normal. The records of such cases could then be more carefully considered before final allocation to their group in the Dunfermline scale.

Hæmatological Technique.

Taking of the Blood Samples.

Myers and Eddy (1938) report entirely reliable results for hæmoglobin on finger blood, having found the average of 111 male subjects to agree exactly with the mean calculated from the more recent findings in the literature.

Capillary samples, in this study, were obtained under conditions of hyperæmia which was induced beforehand with soap and warm water. This greatly promoted capillary circulation before effecting a fairly deep puncture into the digital pulp of the finger, by means of a mechanical stylette. Such a procedure usually ensured a free unrestricted flow without the necessity of external pressure of any kind.

This method of sampling from warmed extremities has been resorted to since several investigators have found that cold can bring about a marked concentration (anhydræmia) of the blood in a vascular region (Bostrom, 1921; Krogh, 1921; Barbour and Hamilton, 1925; Peters and van Slyke, 1932). An increased hæmoglobin concentration of up to 20 per cent. has thus been reported. Cannon *et al.* (1917) is of the opinion that changes produced by cold in the capillary circulation resemble those found during shock.

A slightly disconcerting feature is the big differences in peripheral blood samples drawn simultaneously from different vascular regions of the body (Drucker, 1923; Mackay, 1931; and others). One feels that with careful technique this should not be, for cutaneous blood should present a uniform composition no matter from which region it is derived (Naegeli, 1931; Rud, 1922; and others).

The Hæmoglobin and its Recording.

Bierring (1940) after a study of the reliability of differently standardised hæmometers considers the Danish Sicca-method, based upon the colour of reduced hæmoglobin, superior to any of the acid hæmatin methods such as Newcomer or Sahli, etc., the errors involved in these last-named methods amounting to ± 11 per cent. or more.

Lane (1939), comparing the Sicca method with the ordinary Haldane carbon monoxide method, considers the Sicca probably more accurate as there is less manipulation of the blood.

Barkan (1941) reports that in a series of tests, both low and normal readings obtained on the Sicca agreed most closely with the readings obtained by photo-electric oxyhæmoglobin determination (Evelyn), and in comparison with the van Slyke method the deviation never exceeded

3 per cent. He also found the dispersion of repeated readings on the same sample with the same and with different instruments or glass wedges to be insignificant.

The writer further found that accuracy may be greatly enhanced by doing the readings in a completely dark room with the aid of a strong magnifying lens of such size that both eyes can read at the same time. Under such conditions readings may be observed with an accuracy of ± 1 per cent. by taking the mean of three readings on a specimen. The dispersion of a single reading is about 2 to 3 per cent. under similar circumstances.

The instrument measures by the Haldane standard, whereby 100 per cent. equals 18·5 per cent. oxygen capacity which, on the assumption of Hüfner (1894) that 1 gm. hæmoglobin combines with 1·34 c.c. of oxygen, corresponds with 13·8 gm. of hæmoglobin. The Haldane readings were (by the aid of a slide rule) converted from percentages into gm. per 100 c.c. blood by using this equivalence relation of 100 per cent., Haldane being equal to 13·8 gm. Hence, although recorded to two places of decimals, the hæmoglobin figures throughout this paper must not be interpreted as denoting this degree of accuracy in the readings.

It has always been customary to assume that the iron content of hæmoglobin was 0·335 per cent., but Morrison and Hisey (1935) have made careful analyses which suggest these values to be slightly low. Their analyses indicated a minimum oxygen (and carbon monoxide) capacity of 1·36 c.c. per gm. of hæmoglobin and an iron content of 0·34 per cent. As the ratio between these two figures, however, is the same as between the older ones, their use would not change the comparative results from hæmoglobin involving its oxygen capacity and iron content.

Although Jenkins and Don (1933) have recorded figures for English bloods in agreement with American figures, the general opinion is that the normal hæmoglobin content of the blood in Great Britain is lower than that in America (Price-Jones, 1931, and Wintrobe, 1933). This has led to confusion in the calibration of instruments as shown by the table of methods (Table I) used and the different values, which are all taken to be equivalent to "100 per cent."

It seems most necessary, therefore, that hæmoglobin determinations should be recorded internationally on a common basis, namely, in terms of grammes of hæmoglobin per 100 c.c. of blood as in all other chemical blood determinations, and the hæmoglobin in this study has been recorded in such terms. Attention must also at this stage be drawn to the very recent articles of MacFarlane and O'Brien *et al.* (1944) and King, Gilchrist, and Matheson (1944), in which it is claimed that the Haldane standard really represents 14·8 instead of 13·8 gm. of hæmoglobin per 100 c.c. blood.

TABLE I.

Method.	Gm. Hb per 100 c.c. blood = "100 per cent."
Dare (before 1916)	13·17
(since 1916)	16·90
Haldane	13·80 (see remark below)
Tallquist	13·80
Oliver	15·00
Von Fleischer-Meischer . . .	15·80
Newcomer	16·92
Sahli	17·20

A variation of 13·17 to 17·20 gm.

STATISTICAL ASPECTS.

The experiments described in this paper measure the hæmoglobin in the blood of individuals. As such readings are impracticable on a whole population it is customary to conduct such experiments on suitably chosen samples and to employ statistical methods to deduce results applicable in general.

The literature shows that hæmoglobin values tend to be distributed throughout large samples in accordance with the Normal Law of Probability, and in several instances it was verified that this law does in fact apply to the results here recorded. It is assumed, therefore, that the distribution of values follow Normal laws both in the large samples of experiments and in the parent populations from which these samples were drawn.

A Normal distribution is completely specified by two parameters or statistics, viz.:

(*a*) the arithmetic mean (M),

(*b*) the standard deviation (S.D. or σ) defined thus:—

If $x_1, x_2, \ldots x_N$ denote N observational values then $M = \sum_{i=1}^{i=N} x_1/N$ and $\sigma^2 = \sum_{i=1}^{i=N}(x_1 - M)^2/N$ or $\sum_{i=1}^{i=N}(x_1 - M)^2/(N-1)$, according as N is greater or less than 50 (Σ being the usual sign of summation).

The standard deviation measures the dispersion of the observations about the mean, σ being small when the values cluster about M, and large when they are widely dispersed.

Of values distributed according to a Normal law 68 per cent., 95 per cent., and 99·7 per cent. lie inside the respective ranges $M \pm \sigma$, $M \pm 2\sigma$, and $M \pm 3\sigma$. In common with other workers the term "significant" is used to denote that the values measured lie outside the range $M \pm 2\sigma$.

This test is applied to two sets of numbers which may be proved to be normally distributed. Each sample, as well as its parent population, has its own M and σ from which deductions are drawn:

(*a*) If a large number of samples of size N are drawn at random from the same Normal population M_0, σ_0, their M_i and σ_i will vary from sample to sample but their means, M_i, will themselves follow a Normal law having a mean M_0 and S.D., $\sigma - \sigma_0/\sqrt{N}$.

(*b*) If each of two variables x_1, x_2 is normally distributed having means M_1, M_2, and standard deviations σ_1 and σ_2 respectively, then their differences $x_1 - x_2$ are also normally distributed with mean $M_1 - M_2$ and S.D. (σ) given by

$$\sigma^2 = \sigma_1^2 + \sigma_2^2 - 2r\sigma_1\sigma_2,$$

r being the coefficient of correlation between x_1 and x_2. If there is no correlation then

$$r = 0 \quad \text{and} \quad \sigma^2 = \sigma_1^2 + \sigma_2^2 \quad . \quad . \quad . \quad . \quad (1)$$

Hence, taking for x_1, x_2 the means M_1, M_2 of uncorrelated samples, their differences are normally distributed.

$$\sigma^2_{M_1 - M_2} = \frac{\sigma_1^2}{N_1} + \frac{\sigma_1^2}{N_2} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where N_1 and N_2 denote the numbers in the samples.

This forms the basis of my tests of significance, the difference in two means M_1 and M_2 being regarded as significant if $M_1 - M_2 > 2\sigma_{M_1 - M_2}$

$$> 2\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}.$$

In most cases $M_1 - M_2$ much exceeds $2\sigma_{M_1 - M_2}$.

Differences less than this might arise in random sampling from the same normal population.

For large samples the M_1, σ_1 of the sample afford sufficient approximations to the M_0, σ_0 of the parent population, which are rarely obtainable. The population mean, M_0, then probably lies between $M_1 \pm 2e$ where $e = \sigma_1/\sqrt{N}$ is used in place of $\sigma = \sigma_0/\sqrt{N}$.

For small samples this is not the case and the significance of the results found by the above analysis was therefore checked by using Student's "*t*"

method (Fisher, 1938) which does not depend on an estimate of σ_0. For the difference between two means M_1 and M_2, "t" is defined by:

$$"t" = \frac{(M_1 - M_2)}{\sqrt{\Sigma(x_1 - M_1)^2 + \Sigma(x_2 - M_2)^2}} \sqrt{\frac{(N_1 + N_2 - 2)N_1N_2}{N_1 + N_2}}.$$

As "t" itself is not normally distributed, tables (Fisher, 1938) were consulted in order to estimate the degree of significance of such differences.

I have not mentioned the results of other calculations by means of which I checked and verified my conclusions, *e.g.*

(*a*) I tested 25 samples of the same blood in order to determine the S.D. of the experimental error in reading the instrument. I found $\sigma_E^2 = 0{\cdot}05$ (grammes)^2 and corrected the observed σ, by $\sigma^2 = \sigma_1^2 - \sigma_E^2$, in accordance with (1), to get σ free from reading errors.

(*b*) Sheppard's corrections (Fisher, p. 50) were applied to standard deviations to allow for grouping errors.

Such checks do not affect my conclusions and are, therefore, not here recorded.

Notations used in the Text.

M = Mean.
σ = Standard deviation.
t = Student's "t" for means or differences of means.
n = Number of degrees of freedom.
P = Approximate probability of a deviation greater than t.
r = Coefficient of correlation.

[RESULTS.

Results.

Table I.—Showing Distribution of the Material.

	Malnourished.	Normal.
Europeans 8–16: Males	48	19
Females	68	60
Coloureds 8–16: Males	277	229
Females	132	133
Total	525	441
Total number Males	325	248
Total number Females	200	193
Total (966 subjects)	525	441

About 62 per cent. of the subjects of the malnourished group and about 56 per cent. of the normal group were males. This is important in view of the generally accepted fact that males tend to have slightly higher hæmoglobin values than females. There is, therefore, a likelihood that the mean hæmoglobin level of the "malnourished" group had been pushed slightly up, rather than down.

Table II.

	Malnourished.	Normal.
Number of subjects tested (N)	525	441
Mean Hb Level (gm./100 c.c.)	$13{\cdot}77 \pm 0{\cdot}07$	$14{\cdot}53 \pm 0{\cdot}05$
Standard deviation (σ) *	1·21	1·06
$\sigma/\sqrt{n}$	0·053	0·05

Difference between means $= 0{\cdot}76$ gm.
$2 \times$ S.D. of difference between means $= 0{\cdot}146$.
Difference between groups therefore "significant."

* Calculated from the observations on the individuals.

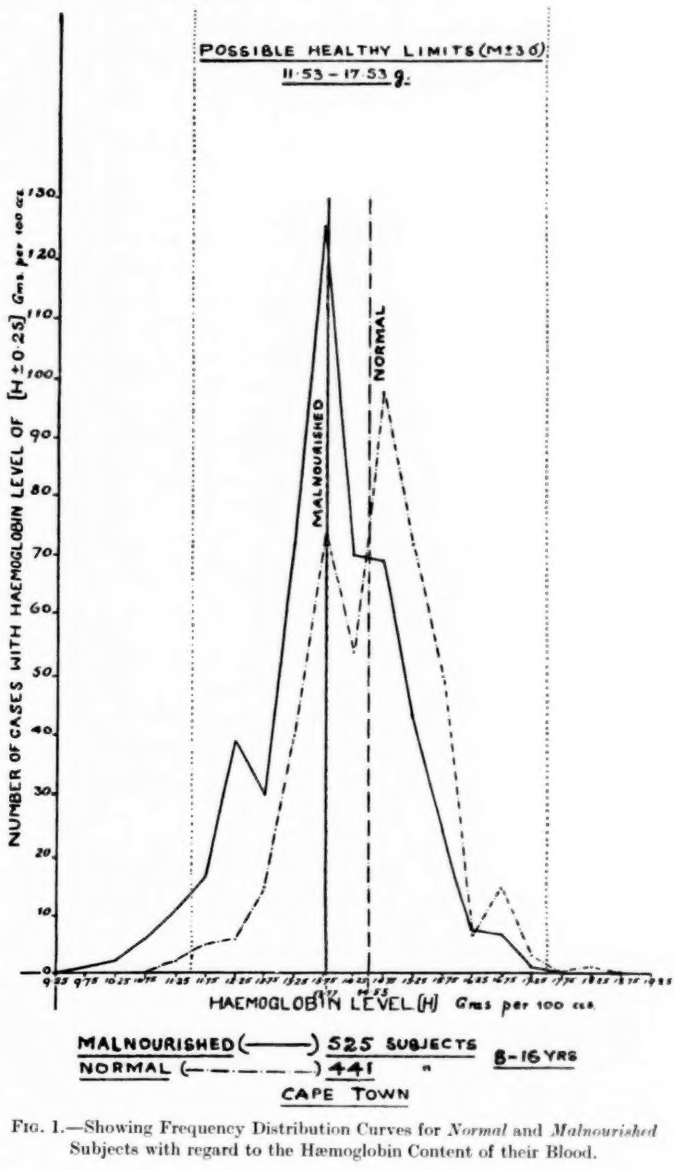


FIG. 1.—Showing Frequency Distribution Curves for *Normal* and *Malnourished* Subjects with regard to the Hæmoglobin Content of their Blood.

TABLE III.—FREQUENCY DISTRIBUTION OF NORMAL AND MALNOURISHED SUBJECTS WITH REGARD TO HB CONTENT.

Hb Level (H).	Malnourished. No. of Cases with Hb Level =(H ±0·25) gm.	Normal. No. of Cases =(H ±0·25) gm.
9·25	0	0
9·75	1	0
10·25	2	0
10·75	6	0
11·25	11	2
11·75	17	5
12·25	39	6
12·75	30	15
13·25	72	40
13·75	125	73
14·25	70	54
14·75	69	98
15·25	43	72
15·75	24	50
16·25	8	7
16·75	7	15
17·25	1	3
17·75	0	0
18·25	0	1
18·76	0	0
Total . .	525	441

CONCLUSIONS.

1. From the results of this experiment based on the blood hæmoglobin findings in 441 normal subjects and 525 malnourished cases, the mean value of the malnourished group was found to be "significantly" lower than that of the normal group, the values being 13·77 and 14·53 gm. respectively.

2. From this can, therefore, be deduced that the hæmoglobin level *is* influenced by the nutritional state of the body. There is, however, such wide overlapping of the data in the frequency curves of the two different groups that the value of the hæmoglobin as an *only* or sole index in nutritional assessment is obviously limited.

3. Many of the children classed in the malnourished group would have been regarded by a casual examiner as being in normal health and might

easily have been included in a "normal" group for establishment of hæmoglobin standards. It is concluded that stricter criteria are probably needed for the selection of such "normal" groups. (The high correlation (·8) found between skeletal and developmental ages of which the former cannot be determined by superficial examination suggests, however, that our groups were suitably selected.)

Summary.

In view of the present widespread adoption of the hæmoglobin level as an index of nutrition, a comparison has been made of the hæmoglobin levels of 441 normal school children and 525 children free from obvious disease but judged by rigorous standards to be malnourished. The results have been submitted to statistical analysis and show a significant difference in favour of the normal group. It is concluded that the hæmoglobin level *is* influenced by the nutritional state of the body but that, owing to the wide overlap between the groups, the hæmoglobin level is of limited value in detecting minor degrees of malnutrition.

II. VENOUS VERSUS CAPILLARY BLOOD: IS THERE A REAL DIFFERENCE IN HÆMOGLOBIN CONTENT?

Introduction.

Physiologically there is very little or no reason to believe that there is a difference in the hæmoglobin content of venous and capillary blood, and a number of authors are in agreement that as far as the red cells and hæmoglobin are concerned there is either complete concordance or close approximation between venous and capillary samples (Duke and Stofer, 1922; Rud, 1922; Ashby, 1925; Wintrobe and Miller, 1929; Price-Jones *et al.*, 1935; Holiday *et al.*, 1935). Only under conditions in which a large quantity of blood is withdrawn from the circulation might this finding not hold (Vaughan and Whitby, 1942).

Significant differences in composition between venous and cutaneous specimens have, however, under normal circumstances been reported by Barbour and Hamilton (1925), Napier and das Gupta (1935), and others. Napier and das Gupta reported a difference of "7 to 11 per cent." in favour of capillary specimens.

Haden and Neff (1924) found lower values in the blood obtained from the large central vessels than from blood obtained from the skin capillaries in infants. De Marsh and co-workers (1941) state that they consistently found the sinus blood of infants to have lower hæmoglobin values than blood obtained from puncture of the heel. Duke and Stofer (1922) encountered no such differences in normal persons or in patients with "secondary" anæmia, but found the capillary red-cell counts to be on an average 17·6 per cent. higher than the venous counts in 8 patients with pernicious anæmia. Strauss and Burchenal (1942) found that the capillary bloods in 80 patients with pernicious anæmia under treatment had approximately 5 per cent. more erythrocytes and hæmoglobin than venous specimens. They suggest that it may be true for normal persons as well, but state that they have insufficient data on this point.

Faergeman (1938 *a*) suggests that unnecessary long and tight application of the tourniquet could be responsible for some extravasation of water into the surrounding tissues giving rise to slight concentration of the hæmoglobin. Ebert and Stead (1940) even recommended the application of tourniquets to the extremities in the treatment of left ventricular failure

since the plasma volume could thus be lowered by transudation of fluid into tissues. On such grounds the finding of Napier and das Gupta may, therefore, be criticised for they brought about momentary congestion by wrapping a piece of tape round the middle phalanx of the finger when taking capillary bloods.

Experimental.

(*a*) *Selection of the Subjects.*

As venous bloods had to be obtained from all the children of the Survey for the performance of various blood tests, a brief remark was made against the name of each child as to the extent of ease with which the blood was taken and at completion of the work a selection of these cases, for statistical comparison, was made as follows:—

(*a*) Comparison of the venous and capillary readings of 258 boys who had "good" veins (fairly prominent and accessible) which allowed the blood to be taken with very little delay or risk of stasis. They were all between the ages of 8 and 13 years, which proved to be the "lean" years in most lads.

(*b*) Comparison of the venous and capillary readings of 84 girls who had "bad" veins. With a small number of exceptions these girls were at or just past the puberty stage when there is a natural tendency for the female body to become more rounded and fat, a condition which also reflects in the state of the arms with the result that the veins become more deeply seated and obscured by adipose tissue. In such cases the tourniquet, therefore, has to be applied a little longer and tighter while the vessel is being located and the blood withdrawn.

It must also be stated that the final numbers, namely 258 boys and 84 girls, comprise only those cases where a hæmotoma had not been raised and where no hæmolysis of any nature had been evident after centrifugation of the blood.

(*b*) *Hæmatological Technique.*

All bloods (both venous and capillary) were taken during the hours of 8.30 and 11.30 a.m. in order to avoid the possible effects of diurnal or temporal variations.

Venous blood was collected in a *dry* syringe from suitable veins in the bend of the elbow, with as little stasis as possible. The tourniquet was applied as late as possible and released as soon as possible. In younger children mere constriction with the hands was often resorted to.

The specimens were collected in flat-bottomed 5-c.c. containers, accurately graduated by means of a circular mark and provided with new rubber stoppers or waxed corks to avoid absorption of plasma. The containers had previously been prepared by measuring into each 0·1 c.cm. of a 2 per cent. potassium oxalate and 0·1 c.cm. of a 3 per cent. ammonium oxalate solution, evaporated to dryness in a hot air oven. This anti-coagulant is so composed that its salt content is supposed to have no effect on the osmotic pressure of the plasma and cell shrinkage need not be allowed for (Whitby and Britton, 1939). Vaughan and Whitby *et al.* (1942) also make special mention of the consistent results which they obtained with this ammonium-potassium oxalate mixture.

It was tried to run the blood into the graduated container without detaching the needle and with its point submerged all the time, such procedure leading to a more accurate adjustment of blood to anti-coagulant, since the formation of a frothy meniscus is thus prevented. After corking, gentle tilting movements ensure quick and complete oxalation.

Capillary samples were obtained under conditions of hyperæmia which was induced beforehand with soap and warm water. This greatly promotes capillary circulation before effecting a fairly deep puncture into the digital pulp of the finger, by means of a mechanical stylette. Such a procedure usually ensures a free unrestricted flow without the necessity of external pressure of any kind or "milking" of the finger.

This method of sampling from warmed extremities has been resorted to since several investigators have found that cold can bring about a marked concentration (anhydræmia) of the blood in a vascular region (Bostrom, 1921; Krogh, 1921; Barbour and Hamilton, 1925; Peters and van Slyke, 1932). An increased hæmoglobin concentration of up to 20 per cent. has thus been reported. Cannon *et al.* (1917) is of the opinion that changes produced by cold in the capillary circulation resemble those found during shock.

Big differences in peripheral blood samples drawn simultaneously from different vascular regions of the body have been recorded (Drucker, 1923; Mackay, 1931, and others). One feels that with careful technique this should not be, for cutaneous blood should present a uniform composition no matter from which region it is derived (Naegeli, 1931; Rud, 1922, and others).

For the recording of the hæmoglobin the Sicca instrument was used, which measures by the Haldane standard and details of which have already been fully described in paper I. As the hæmoglobin readings were read in a dark room it was so arranged with the assistant that the writer did not know whether, at the moment, he was doing a capillary or a venous reading, which excluded all possibility of bias.

RESULTS.

The statistical principles on which my calculations were based and the methods employed have already been fully described in paper I. The results are summarised in Tables I and II as follows:—

TABLE I.

	Venous.	Capill.	V. – C.	P. $\leqslant$	Difference.	Correlation Coefficient r between V. and C.	Composition.
Mean	14·69	14·58	0·11	·005			258 boys, 8–13 years.
σ	0·95	0·89	0·615		Significant	0·80	
Mean	14·83	14·52	0·32	·005			84 girls, round about puberty.
σ	0·89	0·71	0·595		Significant	0·72	

P stands for the probability of the nul-hypothesis, *i.e.* the probability that the difference in the means is due to random sampling, is less than 0·5 per cent.

There is a significant difference between the means for boys and girls. For this difference Student's "t" is equal to 2·73, *i.e.* P is less than 0·0032.

The difference in the variances σ^2 is not significant.

A normal curve fits the differences V. – C. for the 84 girls but not for the 258 boys. The curve for the latter is strongly leptokurtic, *i.e.* it has a peak above the normal curve near the mean (Table II).

TABLE II.

	V. – C.	– 1·38 gm.	– 1·04	– ·69	– ·34	0	·34	·69	1·04	1·38	1·72
258 boys	observed	8	15	14	23	89	46	36	13	12	2
	calculated	3	11	25	44	56	53	37	19	8	2
84 girls	observed		3	5	6	19	21	16	6	6	2
	calculated		2	5	10	17	19	16	10	4	1

Conclusions.

These results show a significant difference in favour of the hæmoglobin content of venous blood in both sexes, but it is definitely more significant in the girls than in the boys.

On the other hand, assuming a correlation coefficient between venous and capillary counts as low as $r=0{\cdot}5$ (the data given by Price-Jones, Vaughan, and Goddard, 1935), there still is a significant difference in favour of the capillary count. *These workers reported that there is no difference in the hæmoglobin content of venous and capillary blood, a conclusion which is not confirmed by these experiments, probably as a result of their neglect of the correlation.*

The discrepancies, therefore, disclosed in the literature and in the above results and the fact that the curve for the boys is so strongly leptokurtic and that the effect is more marked in girls than in boys, suggest that the difference between the hæmoglobin content of venous and capillary blood is perhaps *not* physiological or real. If this difference is encountered it may be necessary to ascertain under what circumstances the sample was obtained. It does not seem impossible that unnecessarily tight and delayed application of the tourniquet gives rise to some extravasation of fluid into the tissues with resultant concentration of the blood.

Summary.

From a detailed statistical analysis of the hæmoglobin content of the venous and capillary bloods of 84 pubescent females and 258 younger males, it is concluded that the venous blood is significantly higher than the capillary blood, and that the discrepancy is greater in the females than in the males. A possible reason for the discrepancy has been suggested.

III. THE EFFECTS OF MEDICINAL IRON ON THE BLOOD OF ANÆMIC AND NORMAL EUROPEAN SCHOOL CHILDREN.

General Considerations.

(*a*) *The Problem of the Action of Iron.*

Although there is abundant evidence that in cases where real iron deficiency anæmia exists iron medication will soon restore the hæmoglobin level to normal, or very nearly so, our theories concerning the metabolism and mode of action of iron in the body are still very imperfect.

In blood studies which deal with normal hæmoglobin standards the question immediately arises as to whether the average or the maximum values should be regarded as the "*normal*" standard. By the maximum value we understand that hæmoglobin value which cannot be raised any further by administration of iron.

Helen Mackay (1931) has shown that the hæmoglobin level of artificially fed babies can be driven higher than that of breast-fed babies by treating them with iron, and she has used these higher figures to construct her normal hæmoglobin curve for infancy. She saw in iron a nutritional element and not a drug.

Widdowson and McCance (1936) studied the effect of iron on the hæmoglobin of a group of normal men and women. The women's hæmoglobin tended to rise and approach the men's level; the men's hæmoglobin showed no change. The lower levels often encountered in so-called normal individuals may, therefore, actually be subnormal according to these findings.

In 1938 Sankaran and Rajagopal confirmed the fact that the hæmoglobin content of the blood in healthy young females could be raised with iron, but they found that the hæmoglobin returned to the original level when the iron was discontinued.

In 1939 Widdowson gave iron to pregnant women in whom the hæmoglobin had begun to show a serious drop. The fall was straightway converted into a rise, but when the iron was discontinued the hæmoglobin fell once more and at about the same rate as if iron had never been administered.

In 1941 the work was carried a stage further by Fowler and Barer who, after administering iron to normal females *and* males, found the hæmoglobin to reach its peak in 10 to 12 weeks and then gradually to fall back

to pre-treatment level even though the administration of iron was continued. In patients with mild grades of anæmia, however, the hæmoglobin *remained* elevated, although below the point of maximum response. This latter finding is an important one in relation to the author's findings, as will be discussed later on.

There can be no question that in cases of hypochromic anæmia, iron therapy corrects the anæmia by rectifying a state of iron deficiency. It is, however, far from certain that a rise in hæmoglobin following iron therapy is always evidence that the patient was previously malnourished in respect of iron, especially when the initial hæmoglobin level was within or near the accepted range of normality. It has lately been questioned whether the supernormal peaks attained by the giving of iron to pregnant and non-pregnant females and to infants are really optimum or physiological levels. It is stated that they are probably just as abnormal as complete saturation with vitamin C.

It was suggested by Widdowson that the administration of iron temporarily raised the level of plasma iron which stimulates the marrow to greater activity. There is, therefore, the vexed question as to whether the effect of medicinal iron in driving normal hæmoglobin standards higher, is due to the correction of a latent iron deficiency state in supposedly normal individuals or whether it is due to an unphysiological stimulus even where there is no iron deficiency.

Experimental.

Two European city orphanages for boys and girls of school age were chosen. From the first institution (A) where the diet was satisfactory 21 girls were selected who, by thorough clinical examination, were found to be perfectly normal in build and health with no history of any recent illness. Fourteen of these girls had not yet menstruated, whereas seven of them had attained puberty. Their ages ranged from 8 to 14 years. They were put on to iron although they were not really anæmic.

The second institution (B) housed inmates of both sexes. The diet here was marked for its high carbohydrate content and lack of enough vegetables. The probability that the diet was, therefore, also poor in iron is great. This conclusion is supported by the fact that 50 per cent. of the children in this institution had low hæmoglobin values, whilst conditions such as bilharzia, malaria, and hookworm infestation, which could give rise to blood loss or destruction, could be excluded.

The subjects were similarly submitted to a clinical examination and 40 "healthy" children with hæmoglobin values lying between 9·7 gm. (70 per cent. Haldane) and 12·47 gm. (90 per cent.) were selected. It is obvious,

of course, that the so-called healthy state did not preclude a state of iron deficiency. Their ages ranged from 8 to 15 years and the numbers were 15 girls and 25 boys.

To avoid the fallacy of centripetal drift they were divided into an experimental group (which was put on to iron) and a control group (no iron) by alternate selection of the names as they appeared on the list in ascending order from 70 to 90 per cent. Haldane respectively. Jung (1938) referred to the fallacy of centripetal drift as being at work whenever one works with tests the results of which may have a perceptible degree of chance error. As the name suggests there is a tendency for extremes on re-examination to gravitate in the direction of the mean for the whole group, whether they be treated or not. Taking more readings on the subjects of the experiment evidently does not lead to greater accuracy.

The readings were done on capillary bloods. The methods employed in the taking of the bloods, recording of the hæmoglobins, and statistical calculation of the results have already been fully described in papers I and II.

Each child received orally two tablets twice daily (four in all) of ferrous sulphate exsiccatus. Each tablet contained about 30 mg. metallic iron. Each child, therefore, received approximately 240 mg. of iron per day which may or may not have been optimum therapy (Brock, 1939).

[RESULTS.

Results.

Table I: Institution A.—Effects of Iron on Hæmoglobin of "Normal" Girls.

	Age.	Initial Hb Level (A1).	After 5 Weeks Fe Treatment (A2).	11 Weeks after Cessation of Fe Therapy (A3).
A. *Menstruating:*				
No. 1 . .	14	15·23	13·85	13·85
2 . .	14	13·03	14·95	13·03
3 . .	14	13·03	13·98	13·37
4 . .	14	13·85	15·37	14·12
5 . .	13	13·03	14·54	13·58
6 . .	12	13·16	14·68	11·92
7 . .	11	12·74	13·58	13·85
Mean Hb . .		13·44 g.	14·42 g.	13·39 g.
Stand. Dev. . .		0·86	0·65	0·74
		(B1.)	(B2.)	(B3.)
B. *Non-Menstruating:*				
No. 1 . .	13	14·54	13·85	14·12
2 . .	13	12·19	13·98	12·47
3 . .	12	13·44	14·40	13·85
4 . .	12	13·85	14·40	13·51
5 . .	11	12·19	14·18	13·16
6 . .	11	12·47	13·85	12·47
7 . .	11	12·88	15·23	13·85
8 . .	9	11·78	14·54	13·37
9 . .	9	11·78	13·98	12·81
10 . .	9	12·88	14·40	13·30
11 . .	9	13·16	15·92	12·88
12 . .	9	14·12	14·68	14·12
13 . .	8	14·54	15·65	13·98
14 . .	8	15·23	15·09	14·88
Mean Hb . .		13·22 g.	14·58 g.	13·48 g.
Stand. Dev. . .		1·00	0·67	0·70

TABLE II.—21 NORMAL GIRLS.

(See Note for notations in this and following tables.)

	A_1, Initial.				A_2, 5 Weeks Iron.						A_3, 5 Weeks Iron + 11 Weeks no Iron.					
	M.	σ.	t.	P.	M.	σ.	t.	n.	P.	r.	M.	σ.	t.	n.	P.	r.
A_1	13·44	·86			·98	1·11	2·36	6	**·05**	− ·46	·05	·93	·14	6	*+ ·90*	*+ ·12*
A_2	·98		2·4	**·01**	14·42	·65					− 1·11	1·10	2·67	6	·025	*− ·26*
A_3	·05		·117	*·45*	− 1·11		3·10	10	**·01**		13·39	·74				

TABLE III.

	B_1, Initial.					B_2, 5 Weeks Iron.						B_3, 5 Weeks Iron + 11 Weeks None.					
	n.	M.	σ.	t.	P.	M.	σ.	t.	n.	P.	r.	M.	σ.	t.	n.	P.	r.
B_1		13·22	1·01			1·37	1·04	4·93	13	**·005**	*·38*	·27	·66	1·51	13	*·10*	**·82**
B_2	26	1·37		3·9	**·005**	14·58	·67					− 1·10	·77	5·00	13	**·005**	*·31*
B_3	26	·27		·80	*·22*	− 1·10		1·04	26	*·15*		13·48	·70				

TABLE IV.

Combined Sets A + B.	M.	O.	t.	n.	P.	r.
$(A_2 + B_2) - (A_1 + B_1)$	1·24	1·65	3·55	20	**·005**	*·2*
$(A_3 + B_3) - (A_1 + B_1)$	·65	·75	·55	20	*·30*	*·58*

TABLE V.

Comparison of	"t".	P.
A_1 and B_1 . . .	·46	*·33*
A_2 and B_2 . . .	·59	*·31*
A_3 and B_3 . . .	·26	*·40*

To summarise: The effect of iron therapy over 5 weeks was to cause a "significant" rise in hæmoglobin, amounting to a mean of 0·98 gm. per cent. in menstruating, and 1·36 gm. in non-menstruating girls. The groups were uncorrelated before and after treatment. This lack of correlation indicates that there are considerable differences in the reactions to iron of individuals. After 11 weeks without iron the girls tended to revert to their pre-treatment levels although still retaining traces of effect.

No significant difference is shown between menstruating and non-menstruating girls.

NOTE.—M = Mean.
σ = Standard deviation.
t = Student's "t" for means or differences of means.
n = number of degrees of freedom.
P = Approximate probability of a deviation greater than t.
r = Coefficient of correlation.

Figures in Clarendon type denote significance.

Figures in Italics denote non-significance.

Figures above the heavy line refer to *differences* in the Hb of the *same individual* under various experimental conditions.

Figures below the heavy line refer to differences between the means of *groups* regarded as uncorrelated.

TABLE VI: INSTITUTION B.—EFFECTS OF IRON ON HÆMOGLOBIN OF "ANÆMIC" BOYS AND GIRLS.

EXPERIMENTAL GROUP (RECEIVING IRON).

Case No.	Age.	Initial Hb Level. (EG1.)	After 8 Weeks' Treatment (EG2.)	After Cessation of Treatment for 5 Weeks. (EG3.)	After Cessation of Treatment for 13½ Weeks. (EG4.)
GIRLS:					
1	15	11·75	15·92	14·68	14·12
2	14	12·47	14·12	13·58	13·51
3	13	12·47	15·65	15·37	15·65
4	14	11·36	14·82	15·92	14·54
5	14	11·78	14·40	13·44	13·85
6	9	12·47	15·09	14·68	14·68
Mean Hb .		12·06 g.	15·00 g.	14·61 g.	14·39 g.
Stand. Dev. .		0·48	0·70	0·98	0·76
BOYS:		(EB1.)	(EB2.)	(EB3.)	(EB4.)
1	9	9·70	13·85	12·88	13·51
2	12	10·74	13·16	13·16	13·44
3	12	10·81	13·51	13·72	13·16
4	12	10·94	13·85	15·23	15·37
5	12	11·08	14·12	14·54	14·54
6	12	11·22	14·54	14·26	15·23
7	13	11·36	14·95	15·92	14·54
8	11	11·43	15·09	15·23	13·98
9	10	11·50	13·85	13·85	14·88
10	12	11·78	14·54	14·54	14·33
11	10	11·78	14·54	13·58	13·30
12	10	12·05	14·18	14·26	15·23
13	9	12·19	15·23	13·58	14·54
Mean Hb .		11·28 g.	14·26 g.	14·21 g.	14·31 g.
Stand. Dev. .		0·66	0·63	0·88	0·78

TABLE VII: INSTITUTION B.—EFFECTS OF IRON ON HÆMOGLOBIN OF "ANÆMIC" BOYS AND GIRLS—*Continued.*

CONTROL GROUP (NO IRON).

				Plus Iron.	
Case No.	Age.	Initial Hb Level. (CG1.)	After 8 Weeks *no* Treatment. (CG2.)	After 4 Weeks Treatment. (CG3.)	After 13 Weeks Treatment. (CG4.)
GIRLS:					
1	14	12·05	12·19	14·68	15·23
2	15	12·47	12·47	15·23	15·23
3	12	11·43	11·92	13·98	15·37
4	11	11·64	11·92	14·54	15·37
5	12	11·78	12·05	14·54	15·23
6	13	11·78	11·78	14·40	14·68
7	12	11·78	11·92	14·95	15·23
8	9	12·47	11·92	13·16	13·85
9	13	12·47	12·47	14·95	14·54
Mean Hb .		11·99 g.	12·07 g.	14·49 g.	14·97 g.
Stand. Dev. .		0·40	0·25	0·63	0·51
BOYS:		(CB1.)	(CB2.)	(CB3.)	(CB4.)
1	10	10·39	10·81	14·54	13·44
2	10	10·81	11·36	14·12	13·85
3	11	11·08	11·08	13·32	13·85
4	11	11·08	11·08	15·78	14·12
5	11	11·29	11·36	14·18	15·09
6	8	11·36	11·78	13·85	14·40
7	10	11·36	11·78	14·54	15·58
8	12	11·78	11·78	14·54	13·85
9	8	11·92	11·92	15·65	15·92
10	11	12·05	12·19	15·23	16·20
11	10	12·19	12·19	15·09	14·68
12	9	12·47	12·47	15·09	15·92
Mean Hb .		11·48 g.	11·65 g	14·66 g.	14·74 g.
Stand. Dev. .		0·61	0·51	0·74	0·97

NOTE.—Although in about 5 per cent. of cases the difference between the means CB1 and CB2 may be due to sampling, the fact that all the differences are positive suggests that a seasonal change in the diet may have influenced the rise.

TABLE VIII.

	Initial.					8 Weeks Iron.						Cessation of Treatment for											
												5 Weeks.						13½ Weeks.					
	EG_1.					EG_2.						EG_3.						EG_4.					
	M.	σ.	*t.*	*n.*	P.	M.	σ.	*t.*	*n.*	P.	*r.*	M.	σ.	*t.*	*n.*	P.	*r.*	M.	σ.	*t.*	*n.*	P.	*r.*
EG_1	12·06	·48				2·94	·85	8·5	5	**·005**	*·07*	2·56	1·13	5·9	5	**·005**	*·15*	2·34	·80	7·2	5	**·005**	*·51*
EG_2	2·94		8·1	10	**·005**	15·00	·70					·39	·82	1·17	5	*·15*	·57	·61	·62	2·39	5	*·05*	*·62*
EG_3	2·56		5·7	10	**·005**	·39		·80	10	·25		14·61	·98					·22	·66	·81	5	·25	*·74*
EG_4	2·34		6·3	10	**·005**	·61		1·48	10	*·10*		·22		·44	10	·35		14·39	·76				

TABLE IX.

	Initial.					8 Weeks no Iron.						4 Weeks Iron.						13 Weeks Iron.					
	CG_1.					CG_2.						CG_3.						CG_4.					
	M.	σ.	*t*.	*n*.	P.	M.	σ.	*t*.	*n*.	P.	*r*.	M.	σ.	*t*.	*n*.	P.	*r*.	M.	σ.	*t*.	*n*.	P.	*r*.
CG_1	11·99	·40		8		·08	·29	·88	8	*·40*	*·69*	2·51	·71	10·6	8	**·005**	·06	2·98	·82	10·8	8	**·005**	*−·62*
CG_2	·08		·52	16	*·30*	12·07	·25					2·42	·48	14	8	**·005**	*·59*	2·90	·56	15	8	**·005**	*·05*
CG_3	2·41		9·5	16	**·005**	2·42		10·7	16	**·005**		14·49	·63					·47	·52	2·76	8	**·01**	*·60*
CG_4	2·98		13	16	**·005**	2·90		15	16	**·005**		·47		1·77	16	*·05*		14·97	·51				

NOTE.—There is no essential difference between the reactions of boys and girls to iron, *e.g.* between CG1–CG4 and CB1–CB4 "*t*" = ·83, P = ·4; and between EB1–EB2 and EG1–EG2 "*t*" = ·81, P = ·22.

TABLE X.

	Initial.					8 Weeks Iron.						Cessation of Treatment for											
												5 Weeks.						13½ Weeks.					
	EB_1.					EB_2.						EB_3.						EB_4.					
	M.	σ.	t.	n.	P.	M.	σ.	t.	n.	P.	r.	M.	σ.	t.	n.	P.	r.	M.	σ.	t.	n.	P.	r.
EB_1	11·28	·66				2·98	·57	18	12	**·025**	*·61*	2·93	·93	11·3	12	**·005**	*·29*	3·03	1·01	10·8	12	**·005**	*·11*
EB_2	2·98		11	24	**·005**	14·26	·63					−·05	·79	·28	12	*·40*	*·47*	·05	·86	·20	12	*·40*	*·26*
EB_3	2·93		12	24	**·005**	−·05		·18	24	*·45*		14·21	·88					·10	·82	·44	12	*·35*	*·51*
EB_4	3·03		11	24	**·005**	+·05		·18	24	*·45*		·10		·31	24	*·40*		14·31	·78				

TABLE XI.

	Initial.					8 Weeks no Iron.						4 Weeks Iron.						13 Weeks Iron.					
	CB_1.					CB_2.						CB_3.						CB_4.					
	M.	σ.	*t*.	*n*.	P.	M.	σ.	*t*.	*n*.	P.	*r*.	M.	σ.	*t*.	*n*.	P.	*r*.	M.	σ.	*t*.	*n*.	P.	*r*.
CB_1	11·48	·61				·17	·21	2·7	11	**·01**	**·94**	3·17	·68	15	11	**·005**	*·45*	3·25	·64	16	11	**·005**	·72
CB_2						11·65	·51					3·01	·69	14	11	**·005**	*·36*	3·09	·65	16	11	**·005**	·75
CB_3												14·66	·74					·08	·86	·31	11	*·4*	*·48*
CB_4																		14·74	·97				

To summarise: the effects of iron therapy for 8 weeks on the hæmoglobin level of "anæmic" girls and boys at institution B were to cause a "significant" rise in both sexes amounting to a mean of 2·94 and 2·98 gm. per cent. respectively, these values being maintained without change after treatment had already ceased for 13½ weeks.

In the control experiment there was no rise in the hæmoglobin after 8 weeks with no treatment. When then put on to iron, however, the girls showed a "significant" rise amounting to a mean of 2·42 gm. after 4 weeks and 2·90 gm. after 13 weeks, the figures for the boys being 3·01 gm. and 3·09 gm. for the same periods.

Discussion and Conclusions.

(*a*) *The Temporary Stimulant Action of Iron on the Hæmoglobin of Normal Girls.*

There are several points of great interest and complexity which arise from the experiments in this study and from similar experiments of other workers.

From Table I it is evident that a "significant" average rise of 1·3 gm. (about 10 per cent. Haldane) could be brought about in the hæmoglobin of normal girls by 5 weeks iron treatment. Widdowson and McCance (1936) reported an increased value of 4 to 17 per cent. with a mean rise of over 10 per cent. in the case of normal women.

The rise in hæmoglobin shown by the normal girls may, therefore, mean either that the so-called initial normal level is not a physiological optimum or, alternatively, that iron medication has a stimulant action on hæmopoiesis distinct from its action in correcting a state of deficiency. If the first view is correct then the increased hæmoglobin concentration of the blood might lead to more efficient tissue metabolism, which might possibly be detectable through studies of the basal metabolism in relation to hæmoglobin levels. That the second view is more probably correct is suggested by the fact that in the "normal" girls the hæmoglobin returned after cessation of medication to a level not "significantly" different from the pre-iron one. This finding agrees with the results of Sankaran and Rajagopal (1938).

(*b*) *The Delayed Decline of the Hæmoglobin in Anæmic Boys and Girls on Cessation of Medication.*

As might have been expected, the hæmoglobin levels of "anæmic" boys and girls responded well to iron medication. In the boys it rose to a conservative normal level of 14·26 gm., whereas in the girls it rose to within the higher limits of normal for females, namely 15·00 gm.

When treatment was stopped the girls showed an apparent tendency to

fall slightly, although after treatment had ceased for 13½ weeks this fall was not yet statistically significant. The "anæmic" boys on the other hand showed not the slightest tendency to fall after iron had already been stopped for 13½ weeks. This does obviously not mean that the rise will

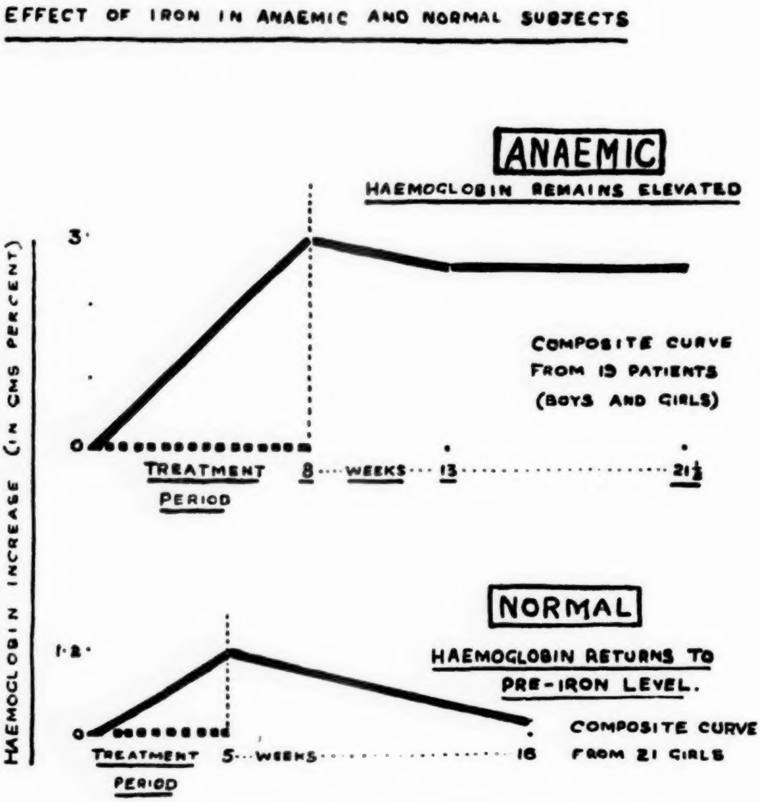


FIG. 2.—Graphs showing the effect of Medicinal Iron on the Hæmoglobin Percentage in "Anæmic" and "Normal" children.

be maintained indefinitely, but the behaviour of the hæmoglobin in the "anæmic" subjects is certainly different from that in the "normals". This tendency of the hæmoglobin to *remain* elevated in the subjects who originally were "anæmic", forms one of the most striking features of these experiments (fig. 2).

Fowler and Barer (1941) also found that on cessation of iron medication the hæmoglobins of the individuals who started with low normal levels fell to pre-treatment level, but that in patients with mild grades of anæmia it remained elevated although not quite at the level of maximum response.

It would, therefore, seem as if the question of how long the hæmoglobin rise induced by iron therapy will be maintained on cessation of treatment depends upon whether the initial hæmoglobin level is subnormal or normal, or probably upon whether there was or was not a state of iron deficiency in the individual before treatment was started.

(*c*) *The Stimulant Action of Iron in General.*

The comments by other workers on some apparent effects of iron on the hæmoglobin have already been referred to. If iron has a stimulating effect on hæmoglobin formation in addition to its action as replacement therapy, there should be a response also in individuals whose blood hæmoglobins are relatively high or at least "normal". This Fowler and Barer were able to prove not only in their females but actually also in 12 normal males, in contrast to the findings of Widdowson and McCance who could only detect it in females.

But there is the further striking observation by Fowler and Barer that after the hæmoglobin has reached a peak there follows a gradual reduction in its level in the blood, regardless of whether or not the iron is given for a period of only 60 days or continuously for a period as long even as 26 weeks. It is strange that the hæmoglobin should fall when the body contains probably more iron than it did while the hæmoglobin was rising. Observations of a similar nature have been commented upon in the case of definitely anæmic individuals by Brock (1937 *a*), Reimann *et al.* (1937), and Josephs (1939). These workers all showed that there is a tendency for the rise in hæmoglobin induced by iron therapy in anæmic individuals to proceed to a super-normal peak and subsequently to decline again even though iron medication is being continued.

These, together with the author's findings, suggest strongly that iron has some stimulating action on the erythron distinct from its function of correcting a deficiency.

If this stimulant action of iron is a reality, there is some evidence that the female sex is more sensitive to it than the male sex. Widdowson and McCance found that whereas normal women responded to iron by a rise in hæmoglobin, normal men showed no response. In the present study there are some apparent, and in some cases statistically significant differences in Tables VI and VII between boys and girls in respect of the rate of hæmoglobin rise, the peak reached and the presence or absence of a decline

following the cessation of treatment. No differences were detectable in Table I between those girls who were menstruating and those who were not menstruating.

Further light on the apparent stimulant action of iron might be thrown by studies of the M.C.H.C. (the mean corpuscular hæmoglobin concentration) value of the blood. It might be expected that when iron produces a rise in the hæmoglobin by correcting a state of deficiency in the body, the rise in hæmoglobin should be accompanied by a rise in the M.C.H.C., if, according to orthodox teaching, the M.C.H.C. value is the only real key to iron therapy. From an investigation (by the author) of this aspect there is definite evidence that it is easier to raise the M.C.H.C. of the blood with iron therapy when the colour index is low than when it is normal.

Another point of great interest is the fate of the iron which is absorbed into the body during iron medication and which is not converted into hæmoglobin. The balance experiments of Brock and Hunter (1937) and of Fowler and Barer (1937) have shown that the amount of this iron is very considerable, and there is a good deal of evidence that when once this iron has been stored in the body it is no longer available for hæmoglobin formation. McCance and Widdowson (1937) have illustrated the failure of the body to excrete iron, and Brock (1937 *a*) has pointed out that in idiopathic hypochromic anæmia the patient may relapse into a state of definite anæmia at a comparatively short period after the administration of very large quantities of iron and at a time when it must be inferred from balance experiments that there are still large stores of iron in the body. Where and in what form this iron is stored is still a mystery. The results of this study, together with the figures of Sankaran and Rajagopal (1938) and others, show that it does not maintain the stimulant action on hæmopoiesis which is evident during the period of administration.

On the other hand, the recent work of Fowler and Barer on normal and slightly subnormal individuals, and of Brock on definitely anæmic individuals, shows that the stimulating action of iron is always of a temporary nature and cannot be, maintained, even for the whole period of administration.

It is apparent that there are many problems concerning the metabolism of iron and the relations of iron therapy to hæmoglobin levels which have not yet been solved. Some of these problems may be answerable through further studies on the mean corpuscular hæmoglobin concentration.

Summary.

A careful study of the response to iron medication of the hæmoglobin in *normal* girls and in *anæmic* boys and girls, suggests that so-called normal

hæmoglobins can be raised by iron therapy and that in addition to its effect in correcting a state of iron deficiency (which results in a deficiency of hæmoglobin), iron also has a temporary unphysiological stimulant effect on hæmopoiesis which drives the hæmoglobin to super-normal peaks.

The question as to how long this stimulant action of the iron will last apparently depends on whether the initial hæmoglobin level is low or normal, a more lasting rise having been observed in those children who started with low hæmoglobins than in those who started with normal hæmoglobins.

It is not yet clear whether the apparent greater sensitivity of the female sex to iron therapy is due to a greater sensitivity to the stimulant action of iron or to a greater prevalence of states of mild iron deficiency. In this study menstruation apparently had no influence.

IV. BLOOD HÆMOGLOBIN STANDARDS FOR SCHOOL CHILDREN IN NORMAL HEALTH AND NUTRITION.

The Reasons for this Investigation.

A series of publications especially during the last decade have established the chief features of the blood of the infant with particular reference to the first year of life (Helen Mackay, 1931; Elvejhem, 1933; Merritt and Davidson, 1933; Andresen, 1935; Magnusson, 1935; Mugrage and Andresen, 1936; Faxen, 1937, and others). The adolescent and adult periods of life have received even greater attention so that it has been possible to compile what may even be termed "international" figures on normal hæmoglobin values for these stages of life (Myers and Eddy, 1938, and Bierring, 1940).

Owing, however, to the inadequate and conflicting nature of the literature the same cannot be said of the normal hæmoglobin standards for children of school age. It is just the period from beginning of school age to pubescence which has been studied much less intently, but which for obvious reasons is not less important. The literature of other countries on the blood of the school child is either very inadequate or conflicting and the same remark applies, *a fortiori*, to a young country like South Africa, where up to now it has been merely assumed that our values approximate those commonly accepted in Great Britain (Gear, 1938).

It is doubtful to what extent the limited information available for European and Bantu children in the Transvaal (altitude 6000 feet) has been founded on an adequate and reliable basis of experimentation, especially as far as the selection of normal subjects is concerned and at the low altitude of the Cape no hæmatological investigations of any kind have yet been conducted on either European or Cape Coloured children.

One of the items on the programme of the Cape Nutrition Survey was the determination of the value of the hæmoglobin as an index in nutritional assessment. It was obvious, however, that the limits of normal had first of all to be established in order to appreciate the real significance of departures from the normal; or differently put, to ascertain what level of hæmoglobin actually constituted anæmia in children under Cape Peninsula conditions.

The Variability of the Normal Range.

Williamson (1916), Rud (1922), and Faergeman (1938 *b*) claim to have found a very close agreement between the hæmoglobin values of adult *females* and "older children". It is not clear though what the exact age range of these "older children" was. The implication, therefore, is that the normal hæmoglobin range for the adult female could be applied with equal success to "older children", and in view of this it is useful to know that Myers and Eddy (1938), having reviewed the results of 22 different investigations in various parts of the world covering about 3000 individuals, were able to compile the following average hæmoglobin figures for adults:—

Females: 13·8 gm. (range 12·96 g.–14·70 g.).
Males: 15·8 gm. (range 14·55 g.–17·04 g.).

This agrees very closely with international figures published 1934–1939 which give 13·6 gm. for women and 15·6 gm. for men (Bierring, 1940).

Osgood and Baker (1935) contend that the red cells of children between 4 and 13 years are smaller than those of adults and contain on an average 20 per cent. less hæmoglobin than those of adults of either sex; and their results, based on 215 white subjects of the Pacific north-west, agreed very closely with those reported in the literature of Europe and America from 1876 to 1933 (Table I). Their criterion of normal, however, seems hardly adequate: a recent physical examination, and at the time the blood was taken the children were stated to be "feeling well".

Then again it seems possible to define the normal hæmoglobin range within certain geographical limits only, the observed range perhaps not even holding good for other parts of the country. Tables I and II do not summarise the whole literature but provide some illustrative examples.

There is, further, enough evidence in the literature to conclude that the hæmoglobin is not in a state of physiological equilibrium and that its level in the blood is likely to be influenced to greater or less extent by certain factors which may or may not always be under control, but which in an experimental study of this nature may be of importance.

Factors which may Influence the Stability of the Hæmoglobin Content of the Blood.

(*a*) The possible influence of the *nutritional state* of the child on the hæmoglobin content of the blood has already been fully discussed in paper I. The decision arrived at was that the hæmoglobin level *is* to a certain extent influenced by the nutritional state of the body, but that the value of the hæmoglobin reading as an *only* or sole index in nutritional assessment has obvious limitations.

TABLE I.—OTHER COUNTRIES.

Authority.	Geographic Location and Altitude.	Age Range, etc.	Hæmoglobin Range (in gm. per cent.).
1. Osgood and Baker (1935)	Europe and America: Summary of all Literature between 1876 and 1933	Majority between 4 and 13 years	Average *12·2* (no ranges given)
2. Osgood and Baker (1935)	Portland, U.S.A. (0–500 feet)	4–13 years	10·0–*12·0*–14
3. Abbott and Ahmann (1939)	Florida, U.S.A. (0–500 feet)	Rural "school children"	50 per cent. below ***9·64***, with 31 per cent. of subjects bordering on this level
4. Faergeman (1938 *b*)	Stockholm (0–500 feet)	8–14 years	11·05–*13·43*–15·82
5. Mugrage and Andresen (1936)	Denver, Colorado (5000 feet)	7–13 years	13·33–*14·2*–14·5
6. Davidson *et al.* (1935)	Aberdeen and N.E. Scotland (0–1000 feet)	"School children"	11·78–*13·16*–14·54

TABLE II.—TRANSVAAL (S. AFR.).

Authority.	Locality.	Subjects.	Hb Range per cent. (100 per cent. = 13·8 g.).	Remarks.
Murray (1932)	Malarious area (N. Tvl.)	543 *Poor White children* (age ?)	58–*69·1*–78	Inaccurate Tallquist method
Gear (1938)	Witwatersrand (5775 feet above sea-level)	132 *Bantu school children* (age ?)	74–*97·48*–129	Lower limit of normal taken to be 80 per cent.
Gear (1940)	Witwatersrand	80 "*Healthy*" *European school children* (6–12 years)	80–*97·3*–110	

(*b*) *Socio-economic Status.*—Although the majority of workers are agreed that there is a definite correlation between low hæmoglobins and poverty or standard of living (Orias, 1930; Napier and das Gupta, 1935; Helen Mackay, 1931; Davidson *et al.*, 1935 and 1938; Linder and Massey, 1939; Hare, 1940, and others), it must be pointed out that socio-economic status can probably only operate through some factor such as poor diet, disease, or parasitism. It can hardly be a factor of importance in itself except as it acts through one of these mechanisms. This, perhaps, more or less explains why in this study the author was unable to prove any "significant" difference between the hæmoglobin level of "normal" European and "normal" Cape Coloured children all of whom were healthy, of satisfactory nutrition, and not suffering from bilharzia, malaria, or intestinal parasites. Osgood and Baker (1935) similarly failed to detect any difference in the hæmoglobin level of the bloods of a large number of children whom they had selected as "normal" cases but who, socio-economically, belonged to different groups.

The remarks of Somerford (1938) in this connection can hardly be omitted from this discussion. In a survey of debilitated and probably anæmic children she concluded that anæmia is not at all just confined to the very poor, the better-off child being often affected to a greater extent than the poorer ones. Several reasons are mentioned for this, chief of which are that the benefits of better housing and purer air are offset by a diminution of food values, more money being diverted from food to clothes, rent and transport fares, and that the very poor supplement their nutrition from sources not at the disposal of those slightly better-off.

In view of the fact that the hæmoglobin level *is* influenced by the nutritional state of the body, it is interesting to note that Batson (1942) was able to prove that in the sample of school children on which this paper is based, malnutrition was proved to be definitely associated with poor socio-economic circumstances.

There is also no doubt that even in good diets iron is found only in comparatively small quantities, being present chiefly in the protective foods such as fruit, dairy products, green vegetables, meat and eggs, which are usually deficient in the diets of people in poor economic circumstances. Such sub-optimal dietary iron intakes, together with factors such as chronic blood loss (*e.g.* through bilharzia, malaria, or intestinal parasites) or deficient absorption or utilisation of iron, may all operate even in individuals passed as normal.

These factors are probably the most important of all in producing the great variation in normal ranges recorded in different parts of the world and at different socio-economic levels.

(*c*) *Effects of Temporal Fluctuations in the Hæmoglobin.*—Temporal

variations in the cellular components of the blood in supposedly normal individuals have been observed for many years. Certain physiological factors such as altitude, temperature, muscular exertion, ingestion of food, etc., have been suggested as contributory causes, but apart from these, rhythmic variations, for which no satisfactory explanation has been advanced, have also been recorded.

It seems logical therefore to suppose that if this is true of the cellular elements of the blood, then it might also be true of the hæmoglobin as an integral part of the red cells—a conclusion supported by the literature—although under normal circumstances this variation in the hæmoglobin from hour to hour and day to day, in the same healthy individual, is probably small. McCarthy and van Slyke (1939) attribute the much greater ranges of diurnal hæmoglobin variations reported in the literature to less accurate methods of analysis, and are of opinion that a certain margin of error must no doubt be allowed for in assessing the significance of changes in the hæmoglobin readings from day to day. They admit the possibility of spasmodic discharges of hæmoglobin from some or other reservoir such as the spleen.

Doan and Zerfas (1927) in a series of 15-minute determinations over 3-hour periods reported a variation in red-cell counts of up to 1·2 million with a variation in the hæmoglobin of up to 11 per cent. Duckles and Elvejhem (1937) report marked daily variations as well as hourly variations which are not consistently comparable at corresponding hours on different days. McCarthy and van Slyke (1939), after having done estimations at 2- or 3-hour intervals from 9 a.m. to 11 p.m. on 18 healthy young men, found the hæmoglobin usually higher in the morning than in the evening, but a subject showing this change on the one day reversed it on another. Dreyer *et al.* (1920) stressed the importance of examining the blood between the hours of 6 and 7 p.m., and in this connection it is of interest to note that Jones (1889 and 1891) found the specific gravity of the blood to be highest between 9 to 10 a.m. and lowest between 6 to 7 p.m.

Ingersoll (1936) found these fluctuations to be more pronounced to women than in men. It is, however, still a controversial question as in whether menstruation and other increased physiologic demands for iron may be responsible for greater instability of the hæmopoietic system.

The results of one case studied by the writer under well-controlled conditions may well be considered. Half-hourly determinations of the red-cell count and hæmoglobin were made over a six-hour period (11.30 a.m. to 5.30 p.m.) on a normal 23-year-old native female who was not pregnant and neither lactating nor menstruating at the time. The patient was kept comfortable and restful throughout with a light midday meal at 12 p.m. and a cup of tea with biscuit at 3.15 p.m.

The blood counts were performed as accurately and as uniformly as possible, although the red-cell count is admitted to have no greater accuracy than ±5 per cent. (Vaughan and Whitby, 1942). The same two pipettes and chamber were used throughout; the average number of cells counted each half-hour equalled 615, and each time the average of three hæmoglobin readings was taken.

Both red cells and hæmoglobin were at their maximal levels shortly after her midday meal, followed by a gradual fall until 4.30 p.m. when the lowest readings were obtained. At 5.30 p.m. perceptible rises in red cells and hæmoglobin had taken place again. During the 6-hour period a variation of 0·9 million in red-cell count, with a corresponding variation of 10·4 per cent. (Haldane) in the hæmoglobin, had been recorded. The figures of Doan and Zerfas (1927) for a single normal individual in their series of tests were 0·8 million red cells and 9 per cent. hæmoglobin over a 3-hour period.

Further evidence confirming the existence of temporal variations in normal blood is provided by Ward (1904), Bierring (1921), Walters (1937), Kenyon and Macy (1938), Moore *et al.* (1939), and Faergeman (1938). Faergeman's work is of special interest since it was done on healthy pupils from public schools in Stockholm.

Although the individual fluctuations during the day are unpredictable, an analysis of the results of McCarthy and van Slyke (1939) shows that the *mean* hæmoglobin of a group decreases during the day in a statistically significant way over the ranges 9 a.m.–11–2 p.m.–5–8–11 p.m., being respectively 0·037, 0·5, 0·068, 0·284, 0·180 gm. The total decrease was 1·068 gm. The corresponding standard deviations are 0·80, 0·68, 0·67, 0·82, 0·72 gm.

There is very little evidence about day-to-day fluctuations. The work of Price-Jones *et al.* (1935) gives 0·18 gm.

No allowance for these diurnal variations has been made in our variances, σ^2, as, although desirable from the theoretical standpoint, the data is insufficient.

(*d*) *Effects of Altitude.*—Despite the considerable theoretical and practical importance of the normal hæmoglobin and red-cell content of the blood at high and low altitudes in this country, there is no published evidence to indicate that there are any real differences in the bloods of dwellers, say, on the Witwatersrand (5750 feet) and at Cape Town (sea-level), which can be attributed only to the difference in altitude between the two places. As a consequence of the lack of data under Cape Town conditions, workers on the Rand have been forced to compare their findings with results obtained under English conditions which correspond roughly with those obtaining at sea-level.

For the many and varied observations by well-known workers on the effect of barometric changes on the physiology of the blood, it seems reasonable to expect that under conditions of reduced pressure or in going from a lower to a higher altitude, there is a tendency towards increase in the red cells with a parallel increase in the oxygen content per unit volume of blood (Viault, 1890 and 1891; Haldane and his colleagues, 1913, in the famous Pike's Peak Expedition; Richards, 1913; Fitzgerald, 1913; Schneider, 1921; Hingston, 1921; Barcroft, 1922, in his famous Andean Expedition; Krupski and Almasy, 1937; Sankaran and Rajagopal, 1938 *b*, and others). And it also seems as if this adjustment to a higher altitude is of a permanent nature which will only be changed by coming to live at a lower level again (Hingston, 1921; Schneider, 1921; Sankaran and Rajagopal, 1938 *b*, and others).

According to Fitzgerald (1913) there is an increase of 10 per cent. above the amount of hæmoglobin present in the body at sea-level for every 100 mm. fall in barometric pressure, the law holding true for both sexes. In the light of Fitzgerald's findings, an estimate of the expected difference between the hæmoglobin levels in Cape Town and the Witwatersrand (nearly 6000 feet) would, therefore, be approximately 15 per cent. Haldane or 2·1 gm.

It is important to note that Fitzgerald's work was carried out not on recently acclimatised people but on permanent dwellers at high and low altitudes respectively. By analogy the position of Cape Town and Witwatersrand children, respectively born and nurtured at sea-level or at an altitude of 6000 feet, becomes a fairly similar one.

Strangely enough Hingston (1921), working on the blood of permanent dwellers at an altitude of 13,000 feet, and Emmerson (1933), studying the effect on the blood of underground workers in the mines on the Rand, both refer to the significant increase or decrease in the red-cell numbers by virtue of which these people are habituated to the different pressures at which they have to live or work. No mention is, however, made of the hæmoglobin; they either paid no attention to it or, in view of the literature, tactfully tried to avoid an argument.

Stammers (1933), on the Rand, using the van Slyke method found the mean hæmoglobin of 12 normal adult males to be 14·6 gm. per 100 c.c. blood, and Buchanan (1935), on the Rand, by determination of the iron content of the blood of a few normal adult males calculated it at 15 gm. If the hæmoglobin is influenced by the high altitude of the Rand, then these figures are not high for adult subjects and least of all for healthy adult males under such conditions.

But the strongest evidence is provided by Liknaitzky (1935) and Symons (1939), both of whom studied the effects on the red-cell and hæmoglobin contents of the blood of people living at the increased altitude of the

Rand. Both of them detected fairly marked increases in the red-cell count but failed to establish hæmoglobin values above the normal average in the same individuals.

The results of Symons, especially, in which he concluded that *the hæmoglobin content at the altitude of the Witwatersrand is, if anything, slightly lower than at sea-level*, are of the greatest significance. He found a marked state of hypochromia of the red cells, which he ascribes to a relative decrease in the hæmoglobin concentration per unit cell volume. He further argues that on physico-chemical grounds this normocytic hypochromic condition of the cells as found by him would be the most efficient for the fullest utilisation of the oxygen-carrying properties of the hæmoglobin, if the concentration of the latter be regarded as a constant.

Further, the figures compiled by Symons, using the oxygen capacity and iron content methods, show practically no difference between hæmoglobin values at coast level in England and at 6000 feet on the Rand, as shown in Tables III and IV (Symons, 1939).

There is, therefore, strong evidence in the work of Symons and others to suggest that unless other important influences such as adverse nutritional or socio-economic conditions are at work on the Witwatersrand, the effects on the hæmoglobin level of permanent residence at an altitude of 6000 feet are not significant. This is what their results suggest; whether it is actually so, is difficult to say at this stage.

(*e*) *The Influence of Climate.*—Although Mugrage and Andresen (1936) have endeavoured to explain the discrepancy between their own hæmoglobin readings and those obtained by Osgood and Baker (1935) by looking upon the climate as a contributory factor, the importance of climate alone is denied by various workers.

Sokhey *et al.* (1937) reported strikingly similar hæmoglobin levels for subjects (19 to 30 years old) from N.E. of the U.S.A. and Indians at Bombay, living under widely different dietetic and climatic conditions. In both instances the hæmoglobin had been determined by the van Slyke methods. They also state that it has not been possible to explain the difference between the comparatively low "normal" content of the blood in Great Britain as compared with that of America, on the grounds of either altitude, age, standard of living, or climatic differences.

Wintrobe (1933) after analysing the results of several hundreds of accurate determinations from various parts of the U.S.A. and Europe concludes that there is no geographic variation in normal blood values.

Myers and Eddy (1938) conclude from their own and a considerable number of other observations the world over that normal adults in good nutrition not residing at excessive altitudes above sea-level, show essentially the same concentration of hæmoglobin in the blood without difference due

TABLE III.—HÆMOGLOBIN VALUES OF NORMAL ADULT MALES IN ENGLAND.

(*Altitude say 0–200 feet.*)

Authority.	No. of Subjects.	Hæmoglobin per Cent.	(Haldane per Cent.)
		Range.	Mean.
Price-Jones *et al.* (1935)	90	90–123	106
Whitby and Hynes (1935)	50	100–126	112
McGeorge (1936)	50	95–125	110
Range		90–126	
Weighted Mean			108·6

TABLE IV.—HÆMOGLOBIN VALUES OF NORMAL ADULT MALES ON THE WITWATERSRAND.

(*Altitude 5750 feet.*)

Authority.	No. of Subjects.	Hæmoglobin per Cent.	(Haldane per Cent.)
		Range.	Mean.
Stammers (1933)	14	101–120	107
Liknaitzky (1935)	60	88–118	105·5
Symons (1939)	46	92–125	109
Range		88–125	
Weighted Mean			106·9

to race or geographical location. The only difference is that due to sex, which has long been recognised.

Few accurate investigations have been made in warm climates and textbooks in tropical medicine adhere to European standards. Kennedy (1939) mentions the wide acceptance of a "tropical anæmia" and Torgenson (1929) makes mention of low erythrocyte counts in the tropics even considering 3·5 million a normal count. Owing, however, to the various pathological factors often operating in tropical areas, the effects of climate may probably also here be discounted as of minor importance.

This, however, cannot be taken to mean that a sudden change of climate

will not even bring about temporary changes in the blood. It is probable that a sudden change of climate may, to greater or less extent, be responsible for certain circulatory reactions at the time, such reactions lasting only until the subject is more acclimatized (Bazett *et al.*, 1940).

An interesting example of an erythrocyte crisis due to a sudden change of climate is mentioned by Pellicciotta (1938) who describes a syndrome which was characterized by a marked fall in the erythrocyte count to an average of 4·2 million accompanied by asthenia, headache, digestive disturbances, and a small, rapid and soft pulse. After a while the subjective symptoms vanished and the red-cell count returned to well over 5 million. It was noticed in soldiers coming from a temperate to a warm climate at a high altitude in Italian Somaliland. He could find no other causative factor except change of climate.

(*f*) *Sudden Environmental Changes.*—The influence of environmental temperature on the blood volume of man was first recognized by Barcroft *et al.* (1922). Recent work has proved that not only is the blood volume consistently increased in the warmth and decreased in the cold, whether artificial or natural, but that distinct parallel increases or decreases in the total hæmoglobin, cell, and plasma volumes may also be expected (Sunderman, 1937; Bazett *et al.*, 1940; Maxfield *et al.*, 1941).

Bazett, especially, reported that the hæmoglobin during such crises sometimes seemed to disappear precipitately, perhaps to appear later again in somewhat lessened amount. There is thus temporary removal of hæmoglobin from the circulation with storage in some reservoir, which, according to Hanak and Harkavy (1924), may be the spleen, from where, according to McCarthy and van Slyke (1939), rhythmic discharges may again take place giving rise to the temporal increases in the blood, already referred to elsewhere.

(*g*) *Miscellaneous Factors.*—With rare exceptions no real differences have been found to exist between the hæmoglobin content of the blood of the two sexes until about puberty (Faergeman, 1938 *b*; and Osgood and Baker, 1935). It is generally recognized, however, that from puberty onwards there is a sudden increase of hæmoglobin in both sexes in comparison with the previous "dormant" period (Wedemeyer, 1939; Borchers, 1936, and this study), the hæmoglobin content of the male bloods tending to be slightly higher than that of the females, from then onwards.

That periods of protracted activity or inactivity may be responsible for destruction or marked variation in the hæmoglobin content of the blood, has been claimed by Orias (1930), Walters (1937), Dreyer *et al.* (1920), and Short (1935).

It is also not at all certain to what extent physiological variations in the hæmoglobin may be caused by ingestion of food or liquid; muscular

exercise or exertion inducing concentration of the blood due to sweating (Emmerson, 1933, and Hare, 1940); humidity factors; cutaneous temperature; menstruation (Moore *et al.*, 1939) or menorrhagia; pregnancy (Kenyon and Macy, 1938), and lactation and, perhaps not quite physiologically, by venous stasis, as suggested by the author in paper II.

Experimental.

The first problem which immediately arose was the question as to what constitutes normal health and nutrition, and for the purposes of this paper normal hæmoglobins have been taken to be those found in the 441 (out of about 1300) children between 8 and 16 years, classed as free from any evidence of present active disease and of satisfactory nutrition, according to the methods and criteria outlined in a previous paper (Brock and Latsky, 1942) and papers I, II, and III.

The hæmatological technique and statistical methods employed have also been fully described in these previous papers.

In addition, it seems necessary, at this stage, to explain the meaning of the term "statistical normal" in relation to this study. When submitting readings, taken on a large number of so-called normal individuals, to a statistical analysis, extreme and, therefore, unlikely values are queried and excluded from the "normal" range and, rightly or wrongly, only such figures as fall within the statistical range of, say, mean $\pm 3\sigma$ are looked upon as lying within possible healthy limits of normal.

It must, however, be made clear that such a normal range in reality corresponds to a theoretical or statistical normal and that normal standards thus determined cannot be regarded as optimum (unless this can be proved) but rather as a range below which all other figures must be regarded as abnormal.

This is essentially the type of "biotypological" approach described by Laugier (1936).

Résults (with Conclusions).

The important conclusion to be drawn from Table VI is, that as far as the hæmoglobin of the blood is concerned there was no real difference between the normally nourished European and the normally nourished Coloured children of this study.

It might, however, be argued that such a conclusion is not justified until small groups of the two races have been compared under controlled conditions of health and nutrition. The conclusion would, however, not be new: Sankaran and Rajagopal (1938) found no lower hæmoglobin values in healthy Indians than in healthy Europeans; Nelson (1937) found no

TABLE V.—MAKE-UP OF THE MATERIAL.

	Males.		Females.		Total.
	8–12.	13–16.	8–12.	13–16.	
European . .	19	. .	37	23	79
Coloured . .	93	136	86	47	362
Total . . .	112	136	123	70	441

TABLE VI.—THE HÆMOGLOBINS OF EUROPEANS VERSUS COLOUREDS.

	No. of Subjects.	Mean Hb.	S.D. (σ).	2 × S.E. of Difference between Means.	Difference between Means.
All *Europeans*, 8–16	79	14·60	1·27	0·30	0·09
All *Coloureds*, 8–16	362	14·51	1·00		

Difference therefore not "significant."

significant differences in either hæmoglobin or red-cell counts between healthy male negroes and healthy white males; Munday *et al.* (1938) failed to establish significant differences in either hæmoglobin or red-cell content in average healthy white and negro infants whose nursing was carefully supervised, and it does not seem as if there is any appreciable difference between the hæmoglobin values of the European and Bantu school children on the Rand referred to in Table XIII.

Lastly, Linder and Massey (1939) in a study of hæmoglobin values in over 200 European and Coloured pregnant women in Cape Town state that "the Coloured, as a whole, have a lower income than the poorer section of the Europeans, but their mean hæmoglobin is not lower; this may be due to a larger proportion of the Coloured income being spent on food, to a more fortunate selection of the foods consumed, and to a greater assistance from charity".

TABLE VII.—HÆMOGLOBINS IN MALES AND FEMALES BEFORE AND AFTER THEIR TWELFTH YEAR: ALSO MALES VERSUS FEMALES.

	No. of Subjects.	Mean Hb.	S.D. (σ).	2 × S.E. of Difference between Means.	Difference between Means.	Result.
All *males* (Eur. and Col.), 8–12 . . .	112	14·48	1·00	0·27	0·31	*Signific.*
All *males* (Eur. and Col.), 13–16 . .	136	14·79	1·14			
All *females* (Eur. and Col.), 8–12 . . .	123	14·22	1·10	0·30	0·41	*Signific.*
All *females* (Eur. and Col.), 13–16 . .	70	14·63	0·95			
All *males* (Eur. and Col.), 8–16 . . .	248	14·65	1·05	0·21	0·28	*Signific.*
All *females* (Eur. and Col.), 8–16 . . .	193	14·37	1·10			

Boys therefore tend to have higher hæmoglobins than girls, and in both sexes there is a "significant" increase of the hæmoglobin after the 12th year of life in comparison with the previous 8- to 12-year period.

Further details relating to Table VII are shown in Tables VIII, IX, X and in fig. 3.

TABLE VIII.—SHOWING FREQUENCY DISTRIBUTION OF EUROPEAN AND COLOURED CHILDREN COMBINED.

Hæmoglobin Level (Hb) (gm./100 c.c.).	Number of Cases with Hæmoglobin Level of Hb – 0·25 gm./100 c.c.			
	Males.		Females.	
	Age 8–12.	Age 13–16.	Age 8–12.	Age 13–16.
10·75	0	0	0	0
11·25	1	1	0	0
11·75	1	1	2	1
12·25	1	1	3	1
12·75	2	3	7	3
13·25	10	9	19	2
13·75	24	20	19	11
14·25	15	14	16	9
14·75	23	24	32	18
15·25	18	28	11	14
15·75	13	19	12	7
16·25	2	3	0	2
16·75	1	10	2	2
17·25	1	2	0	0
17·75	0	0	0	0
18·25	0	1	0	0
18·75	0	0	0	0
TOTAL . . .	112	136	123	70

In the following two tables the separate figures for boys and girls are statistically analysed:—

TABLE IX.—STATISTICAL ANALYSIS OF THE RESULTS OF 248 NORMAL BOYS, 8–16 YEARS.

	Hæmoglobin (gm. per 100 c.c. blood).	
	Boys, 8–12.	Boys, 13–16.
No. of subjects (N) . .	112	136
Mean (M)	$14{\cdot}48 \pm 0{\cdot}10$	$14{\cdot}79 \pm 0{\cdot}10$
Standard deviation (σ) .	1·00	1·14
$\sigma/\sqrt{N}$	0·10	0·10
Possible healthy limits ($M \pm 3\sigma$) . . .	11·48–17·48	11·37–18·21
Observed healthy limits .	10·39–16·62	11·36–18·00
Lower limits of range $M \pm \sigma$.	13·38 gm.	13·55 gm.

TABLE X.—STATISTICAL ANALYSIS OF THE RESULTS OF 193 NORMAL GIRLS, 8–16 YEARS.

	Hæmoglobin (gm. per 100 c.c. blood).	
	Girls, 8–12.	Girls, 13–16.
No. of subjects	123	70
Mean (M)	$14{\cdot}22 \pm 0{\cdot}10$	$14{\cdot}63 \pm 0{\cdot}11$
Standard deviation (σ)	1·10	0·95
$\sigma/\sqrt{N}$	0·10	0·11
Possible healthy limits ($M \pm 3\sigma$)	10·92–17·62	11·78–17·52
Observed healthy limits	11·78–16·62	11·78–16·62

ANÆMIA.

The hæmoglobin values which certainly indicate anæmia can now be deduced from the following table:—

TABLE XI.—SHOWING APPROXIMATE HB VALUES TAKEN TO CONSTITUTE ANÆMIA IN CHILDREN, 8–16 YEARS, FROM THE RESULTS OF THIS STUDY.

Sex and Age.	Hb Level of Blood Constituting Anæmia.
A. Boys, 8–12	*Below* 11·48 g. per 100 c.c. or approx. 82·5 per cent. Haldane.
Boys, 13–16	*Below* 11·37 g. per 100 c.c. or approx. 82 per cent. Haldane.
B. Girls, 8–12	*Below* 10·92 g. per 100 c.c. or approx. 78 per cent. Haldane.
Girls, 13–16	*Below* 11·78 g. per 100 c.c. or approx. 85 per cent. Haldane.
C. Boys and Girls, 8–16	Approx. *below* 11·39 g. per 100 c.c. or approx. 82 per cent. Haldane.

A safe general rule would, therefore, be to regard any hæmoglobin value below 11 gm. (or 80 per cent. Haldane) as definitely constituting anæmia in children between 8 and 16 years.

"Low Normal" versus "High Normal" Hæmoglobins.

Of any Nutritional Significance?

It is obvious though that the conventional Mean $\pm 3\sigma$ range of possible healthy limits of normal (about 11 to 18 gm.) is probably too wide a one for useful application. If this range is, however, reduced to the conservative one of mean $\pm\sigma$, then the *lower* limit of this latter value (as applied to the 441 "normals") lies between 13·02 and 13·57 gm. per cent. (or, say, at approximately 13 gm.) for both sexes at any age between 8 and 16 years.

The question arises as to whether there is any nutritional significance between hæmoglobin figures lying, say, *between* 11 and 13 gm. and figures lying *above* 13 gm., in the 441 "normal" children of this study; in other words, is there a possibility that figures between 11 and 13 gm. may be sub-optimal (in the sense that they are due to, say, iron deficiency and can be raised by a better diet) and that figures above 13 gm. are perhaps optimal (in the sense that they cannot be raised by a better diet)? This question has perhaps been partly answered in paper III, but will be more fully answered in a following paper.

The Biphasic Phenomenon.

Reference to fig. 3 reveals the presence of two peaks in the frequency curves, which although not prominent in the females become very noticeable in the males. The peaks further tend to occur at approximately the same levels in the sexes, namely 13·8 gm. (100 per cent. Haldane) and 14·8 gm. (106·5 per cent. Haldane).

A likely explanation for this is that the group of children classed together as normal are not homogeneous, but from Table VI it obviously does not represent a difference between Coloured and Europeans since their bloods showed no significant differences, and in the 13- to 16-year male group (comprising no Europeans) the double-peak is just as evident.

If it could be shown that the majority of the readings which constitute the left-hand component of the biphasic curve were derived from the younger children and that the right-hand component chiefly represented the readings derived from the older children within the 8- to 12- and 13- to 16-year groups respectively, the presence of the double peak would suggest the possibility of a further division of the subjects within the two sub-groups, with regard to their normal hæmoglobin values. This analysis revealed the following:—

[Table XII.

TABLE XIIA.—DISTRIBUTION OF HÆMOGLOBIN VALUES IN RELATION TO AGE IN 112 BOYS (8–12 YEARS).

Hb Range (gm. per cent.).	8–10 Years.	10–12 Years.	Totals.
11·25–14·25 . . .	26	28	54
14·75–17·25 . . .	28	30	58
	54	58	112

TABLE XIIB.—HB VALUES IN RELATION TO AGE IN 136 BOYS (13–16 YEARS).

Hb Range (gm. per cent.).	13–14 Years.	14–16 Years.	Totals.
11·25–14·25 . . .	28	21	49
14·75–18·25 . . .	47	40	87
	75	61	136

From both tables it is, therefore, evident that the two-peak phenomenon cannot be due to age differences within the smaller groups, and that further division of the two age groups 8 to 12 and 13 to 16 would be of no value.

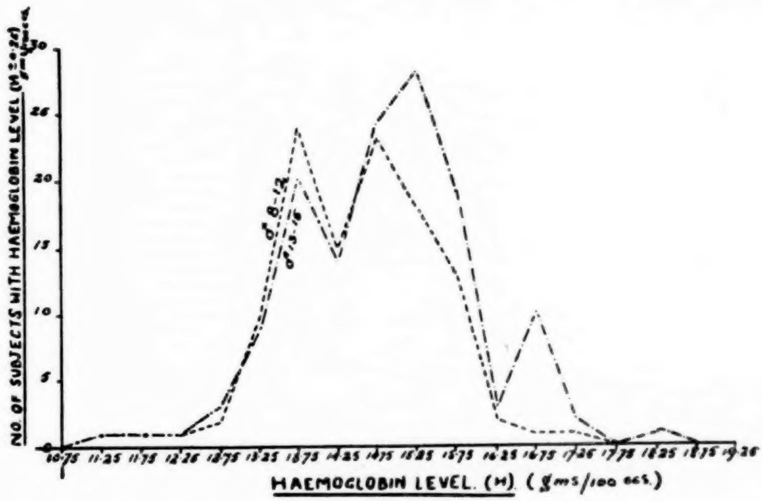
In summary it can, therefore, be stated that the biphasic phenomenon is probably not due to differences between Europeans and Coloureds, to sex differences, or to age differences, within the sub-groups.

It also seems unlikely that the "Normal" and "Excellent" groups of the Dunfermline Scale would correspond with the two peaks, since these two groups merge so imperceptibly into each other. The number of "Excellent" subjects was also relatively small in comparison with the number of "Normals".

Until further comparisons between the individuals whose blood values make up the two component curves become possible, the interpretation of the double peak can, however, only be guessed at.

The discovery of the phenomenon is, however, not new. Symons (1939) found similar double peaks on the Rand with regard to the red-cell count of *normal* persons and deduced that there were two types of normal individuals on the Rand: one showing an erythrocytosis, and the other not.

A last point of note is that in the curve of the 13- to 16-year old males there is evidence also of a small third peak. On analysis, the records of



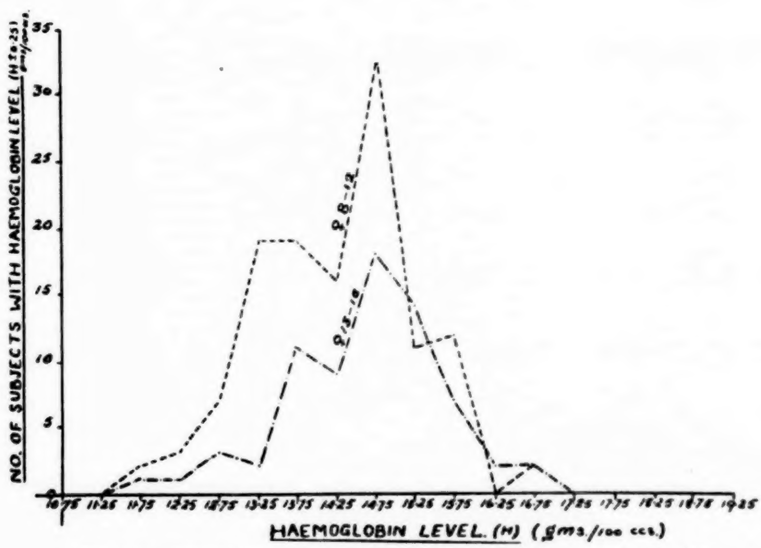


Fig. 3.—Showing frequency distribution curves of 248 boys and 193 girls between the ages of 8 and 16 years with regard to the Hb level of the blood. They were classed as healthy and of satisfactory nutrition.

these 10 males showed that they were not only relatively "old" children (15 to 16¼ years) but that they were also of extraordinarily healthy robust build, their bodies being muscular and well-developed through active participation in school sport. They were, in other words, super-normals and there is, therefore, just the suggestion that there may be a correlation between the hæmoglobin and developmental levels.

COMPARISON OF HÆMOGLOBIN FIGURES OF CAPE TOWN CHILDREN WITH WITWATERSRAND CHILDREN.

TABLE XIII.

	Witwatersrand (5775 feet) (Gear, 1938 and 1940).	Cape Town (sea-level) (this Study).
A. *Europeans only.*		
No. of subjects . .	80	50 (37 F. and 13 M.)
Age limits . . .	6–12 years	8–12 years
Mean Hb . . .	13·42 gm.	14·51 gm.
Observed Hb range . .	11·08–15·23 gm.	11·36–17·31 gm.
B. *Coloured Races.*	*Bantu.*	*Cape Coloured.*
No. of subjects . .	132	362
Age limits . . .	? (School children)	School children, 8–16
Mean Hb * . . .	13·45 gm.	14·51 gm.
Observed Hb range . .	10·26–17·86 gm.	11·36–18·00 g.

* Linder and Massey (1939) have found a "significant" difference between the Hb of Native women and that of Cape Coloured women in Cape Town, the Hb of the Natives being lower than that of the Coloureds.

It is unfortunate that the subjects of Table XIII were not comparable in all other respects besides altitude of habitat, the chief differences probably being in respect of race, age, socio-economic status, food habits, and the criteria employed for their selection.

In the Interim Report of the Nutrition Survey (1939) it is stated that of the four provinces the incidence of malnutrition is greatest in the Transvaal and that there is a striking lack of vegetables and fruit in the diets of children in that Province. Such being the case amongst Europeans, it is reasonable to deduce that among the Bantu children on the Rand the position would be worse.

The ideal procedure would, obviously, have been to have compared the bloods of two comparable groups of subjects born and nurtured in Cape

Town and Johannesburg respectively and preferably selected by the same worker(s) in both places.

In this study the normal hæmoglobin range was considerably higher than the range recorded on the Witwatersrand (6000 feet) for supposedly normal children. This difference may be interpreted in at least three ways.

(*a*) That permanent residence at the altitude of the Witwatersrand does not raise the hæmoglobin level in children as compared with children living in Cape Town at sea-level. Symons, whose extended observations on the Rand must be carefully considered, came to the definite conclusion that the hæmoglobin content of the blood is not increased by residence on the Witwatersrand; or (*b*) the Cape Nutrition Survey may have set a higher standard for selecting nutritionally normal children than was set by the Witwatersrand surveys. For this statement there are some very good reasons, and to the author it seems to be a very likely explanation; or (*c*) there may be factors concerned neither with the difference in altitude nor with the nutritional state which adversely affect the hæmoglobin level of Witwatersrand children.

Until such time, however, as an effectual comparison of bloods could be arranged on the lines suggested elsewhere, it would be unwise to arrive at a dogmatic conclusion concerning the reasons for the difference (whether real or apparent) in the hæmoglobin levels of Cape Town and Johannesburg children.

Summary.

In this study the need for the establishment of normal hæmoglobin standards for children has been overcome by using figures from 441 healthy Cape Peninsula school children of satisfactory nutrition, both European and Coloured and of both sexes, between the ages of 8 and 16 years. They had been selected most carefully from more than 1300 children. The methods employed in this selection have been carefully described elsewhere (papers I, II, III). The following is a summary of the findings:—

	Boys.		Girls.	
	8–12 Years.	13–16 Years.	8–12 Years.	13–16 Years.
Mean Hb (M) in gm./100 c.c. blood . .	$14{\cdot}48 \pm 0{\cdot}10$	$14{\cdot}79 \pm 0{\cdot}10$	$14{\cdot}22 \pm 0{\cdot}10$	$14{\cdot}63 \pm 0{\cdot}11$
Possible healthy limits ($M \pm 3\sigma$)	11·48–17·48	11·37–18·21	10·92–17·52	11·79–17·48
Lower limits of $M \pm \sigma$ range .	13·38 gm.	13·55 gm.	13·02 gm.	13·57 gm.

A safe general rule would, therefore, be to regard any hæmoglobin value below 11 gm. (or 80 per cent. Haldane) as constituting definite anæmia and an indication of departure from normal health or nutrition, of past or present origin.

(Attention must, however, be drawn here to the very recent article of MacFarlane and O'Brien *et al.* (1944) in which it is claimed that the Haldane standard really represents 14·8 instead of the usual 13·8 gm. of hæmoglobin per 100 c.c. blood. If this finding is, or should later on be, accepted as correct, the figures of this study will, of course, have to be slightly revised accordingly, before application in survey or clinical work.)

The frequency distribution curves present a two-peaked appearance which could be shown not to be due to racial, sex, or age differences. It is pointed out, however, that this phenomenon is not new.

By further statistical analysis it could be shown that boys tend to have higher hæmoglobins than girls and that in both boys and girls there is a "significant" increase in the hæmoglobin after the 12th year in comparison with the previous 8- to 12-year period.

No real differences were found in the hæmoglobin of healthy normally nourished Europeans and Coloureds.

Besides the important effect of nutrition, other factors such as socio-economic status, temporal fluctuations in the composition of the blood, climate or sudden environmental changes and the altitude of the Witwatersrand, have been discussed in relation to their possible disturbing influences on the physiological equilibrium of the hæmoglobin level.

In this study the normal hæmoglobin range was higher than the range recorded on the Witwatersrand (6000 feet) for supposedly normal children. The reasons for the difference is not clear, but a most likely explanation seems to be the higher standard that was set by the Cape Nutrition Survey for selecting nutritionally normal children in comparison with that set by the Rand surveys, which, relatively, also comprised much smaller numbers of children.

It is suggested that the conventional possible healthy range of Mean $\pm 3\sigma$ (about 11 to 18 gm.) is probably too wide a one for *useful* application. A more conservative range would be Mean $\pm\sigma$, the *lower* value of which is about 13 gm. for all the "normal" children of this study. In a following paper the main objective would be to discover whether there is any nutritional significance between hæmoglobin figures lying, say, *between* 11 and 13 gm. and those lying *above* 13 gm. per cent.

V. THE NUTRITIONAL SIGNIFICANCE OF LOW-NORMAL VERSUS HIGH-NORMAL BLOOD HÆMOGLOBINS.

Introduction.

In the previous paper it was established that the possible healthy limits of a normal (Mean $\pm 3\sigma$) hæmoglobin range for school children were between 11 and 18 gm. per cent., but it was also stated that such a "statistical normal" was probably too wide a one for useful application in actual survey or clinical work.

It was, therefore, decided to reduce this "normal" Mean $\pm 3\sigma$ range (the lower limit of which is about 11 gm.) to Mean $\pm \sigma$ only and to make a further special study of hæmoglobins lying *between* 11 and 13 gm. (the latter figure being approximately the lower limit of the Mean $\pm \sigma$ range) and hæmoglobins *above* 13 gm. respectively.

Experimental.

Three different methods of study were employed:

(*a*) Both normal and anæmic children were put on to medicinal iron for a period of time and the blood reactions carefully studied (paper III).

(*b*) There were reasons for thinking that the lower levels of hæmoglobin found in the 441 "normal" children of the present survey and in other so-called normal series may really represent a slightly subnormal condition due, chiefly, to mild degrees of iron deficiency, of which the mean corpuscular hæmoglobin concentration (M.C.H.C.) value of the blood is supposed to be a sensitive index and the real key to iron therapy.

(*c*) If hæmoglobin figures between 11 and 13 gm. in so-called normal children cannot be considered as optimal in the sense that they are due to dietary deficiencies, correction of which will probably cause an increase in the hæmoglobin, then it finally remains to be proved that figures above 13 gm. can be considered as optimal, in the sense that they can *not* be raised by a better diet.

A. The Mean Corpuscular Hæmoglobin Concentration (M.C.H.C.) Value of the Blood in Nutrition Work.

(*a*) *Definition.*

Closely related to the hæmoglobin content of whole blood is the M.C.H.C., a value pertaining to the red cells only and depicting the number of grams of hæmoglobin per 100 c.c. of *cells* as distinct from whole blood. It represents the ratio between the hæmoglobin content and the mass of the red cells.

(*b*) *Practical Applications.*

The Normal M.C.H.C. range is supposed to be 32 to 38 gm. with an average of 34 gm. per 100 c.c. packed red cells. According to Whitby and Britton (1939), the M.C.H.C. is usually below 32 gm. per cent. in cases of genuine iron deficiency, it being held to be the only real key to iron therapy.

In the customary usage of the term a low M.C.H.C. cannot be called anæmia. It does, however, almost certainly indicate deficient hæmoglobinisation of the red cells, and since this is most commonly due to iron deficiency it may be that the M.C.H.C. is a more sensitive index of iron deficiency than is the hæmoglobin percentage. From Table I it is evident that there were normally nourished children in whom the M.C.H.C. was below 32 gm. although their hæmoglobin figures were within the limits of normal, *i.e.* above 11 gm. per cent. In all "malnourished" children with hæmoglobins below 11 gm. the M.C.H.C. was below 32 gm. per cent.

The M.C.H.C. takes no account of the number of red cells, but is concerned solely with the volume occupied by them in whole blood and the degree to which they are saturated with hæmoglobin. It, therefore, differs from the mean corpuscular hæmoglobin (or mean hæmoglobin content per cell), which expresses the absolute hæmoglobin content of a single cell in micro-micrograms, corresponding very closely to the colour index and which depends on the numerical red-cell count. The M.C.H.C., therefore, has the advantage that for nutrition survey purposes it is less time-consuming than is the calculation of other indices which depend upon red blood cell counts.

(*c*) *The Constancy of the M.C.H.C. in Normal Humans.*

A study of the literature reveals the fact that the M.C.H.C. value is strikingly constant in all normal humans (Wintrobe, 1929; Osgood and Baker, 1935; Mugrage and Andresen, 1936; Faergeman, 1938; Guest, 1938, and others). One feels that although their observed ranges may have included readings below 32 gm. or above 38 gm., such readings must be looked upon as exceptions since none of these workers has recorded average values below 33 gm. or above 35 gm. per cent., either in normal children of school age or in normal adults. In fact, Faergeman, comparing his own findings in school children 8 to 14 years old with that of Wintrobe on adults, concludes that although the erythrocytes may be smaller or may contain less hæmoglobin than those of adults, the M.C.H.C. of children (regardless of age or sex) does not differ from that of adult males or females. Guest recorded 33·3 gm. for cord blood, 34·5 gm. for a 1- to 10-day old infant and 34·4 gm. per cent. for a normal 4-year old child.

From the author's observations it can at least definitely be stated that whatever the size of the cells of an individual, the cells seem to be unable to

hold more than a 38 per cent. saturation, for in no instance was this limit ever exceeded in hundreds of determinations.

In view, therefore, of these facts the orthodox normal range of 32–34–38 gm. per cent. as recommended by Whitby and Britton (1939) was used as the criterion of iron deficiency in Table I.

(*d*) *The Possibility of Undetected Iron Deficiency in so-called Normals in the Light of the M.C.H.C. Readings.*

If the claim that a low M.C.H.C. always indicates iron deficiency is correct, whilst low hæmoglobin or low hæmatocrit readings may be due to other causes, then the following table should help to give a further answer to the question whether hæmoglobin figures between 11 and 13 gm. can be improved by a better diet; or, in other words, whether they can be regarded as optimal or not.

TABLE I.—SHOWING EXTENT TO WHICH HÆMOGLOBINS BETWEEN 11 AND 13 GM. ARE ASSOCIATED WITH PROBABLE IRON DEFICIENCY (LOW M.C.H.C. VALUES) IN 331 (OF THE 441) "NORMALS".

M.C.H.C. (gm./100 c.c. *Packed* Red Cells). .	HÆMOGLOBIN (gm. per 100 c.c. *Whole* Blood). 11–13 gm.	Above 13 gm.
BELOW 32 gm. . .	17 subjects (11–11·8–12·8 gm.)	. .
ABOVE 32 gm. . .	3 subjects (11·5–11·9–12·9 gm.)	311 subjects
TOTAL (331)* . .	20 subjects (M.C.H.C. range 29·5–30·2–31·4 gm.)	311 subjects (13·1–14·6–18 gm.)

* The remainder of the "Normals" were excluded either because venous blood could not be obtained for personal reasons, or because enough was not obtained to get a correct adjustment to the anti-coagulant, or because the supernatant plasma showed a trace of hæmolysis after centrifugation.

The above table shows a very close association between hæmoglobins between 11 and 13 gm. per cent. and an M.C.H.C. below 32 gm. per cent. It strongly suggests that hæmoglobins between 11 and 13 gm. per cent. in "normal" children are due to undetected iron deficiency.

(*e*) *Absence of Morbid Factors.*

There is also enough reason to believe that the 17 subjects concerned were not suffering from parasitic infestation, chronic blood loss, or gastro-intestinal disorder, which might have been responsible for loss of iron, for deficient absorption from the gut, or for depressive action on the hæmopoietic tissues. This not only applies to the 17 children under discussion but to all the 441 children from whom the normal figures were derived.

(*f*) *Conclusions.*

The obvious conclusion, therefore, is that the 17 subjects were probably suffering from dietary iron deficiency, or, differently put, that they were malnourished in respect of iron. There was, therefore, undetected iron deficiency notwithstanding the stringent clinical examination and tests which had to be passed in order to qualify as so-called Normals. Only by means of the M.C.H.C. readings was the detection of this latent iron deficiency made possible.

It further seems reasonable to expect that unless there is undetected disease, the hæmoglobins of these 17 subjects would be correctable by a better diet, under which circumstances they cannot be considered as representing optimum.

But what about the remaining 3 subjects who also had hæmoglobins between 11 and 13 gm. but with normal M.C.H.C. readings?

It is possible that the hæmoglobin figures of these 3 subjects may reflect a state of deficiency of essential hæmopoietic factors other than iron. Such factors according to Vaughan (1938) may be vitamin C, the extrinsic factor of Castle (P.A. factor), thyroid, and possibly copper.

In view of these facts, and more especially in view of the definite association of hæmoglobins between 11 and 13 gm. with iron deficiency, it seems more correct to consider figures between 11 and 13 gm. as probably sub-optimal, although still within the range of possible healthy limits of normal.

It is also of interest to know that only 28 out of 441 children had hæmoglobins between 11 and 13 gm., which could be taken as further proof that the "normals" had been very satisfactorily selected.

However, how did it happen that, notwithstanding stringent clinical and laboratory examinations, these 20 children had been missed and passed as healthy and normally nourished?

The probable explanation for this is that the dietary deficiency was of such a nature that it did not interfere with the general aspect of somatic growth and efficiency by which malnutrition is detected in a clinical examination.

The somatic aspects may also not actually reflect the dietary intake, for the conclusions of the Cape Nutrition Survey (Brock and Latsky, 1942) are that there is a strong suspicion that the differences between the two upper groups (Excellent and Normal) of the Dunfermline scale depend to a considerable degree upon skeletal and somatic growth which may be more dependent upon the hormonal influences of puberty than upon nutrition.

From what has been written so far it would appear that the very limited value of the hæmoglobin in detecting malnutrition may be due to the fact that the lower limit of normality has been set too low, *i.e.* 11 gm. instead of 13 gm.

It is apparent from Table I that if anæmia be defined as a hæmoglobin level of less than 11 gm. per cent., then iron deficiency as represented by an M.C.H.C. of less than 32 gm. per cent. can exist without anæmia. Such a finding finds support in a statement by Henderson (1942), namely, that normal hæmoglobin readings cannot always be correlated with optimal dietary intake of iron.

It has not yet been proved that an M.C.H.C. of less than 32 gm. can always be permanently raised by iron therapy. If this were the case then the M.C.H.C. could be regarded as a very sensitive index of iron deficiency.

In the meantime, however, it is suggested that whenever the hæmoglobin is used in nutrition surveys it should be supplemented by the M.C.H.C. at least in those cases whose hæmoglobin is less than 13 gm. per cent. or within the lower limits of normal.

B. Effects of an Optimal (or Near-Optimal) Diet on Hæmoglobins above 13 gm. per Cent.

(*a*) *The Subjects.*

Under the conditions of the Survey it was not possible to attain fully controlled conditions in a large number of the remaining 413 "normals", who were scattered all over the Peninsula in separate homes.

Forty-two of the above 413 children (who had hæmoglobins above 13 gm.) were, however, resident in an institution where, under reasonable conditions of health and hygiene, a small well-controlled experiment was conducted by putting these children on to an optimal (or near-optimal) diet for an unbroken period of 10 months.

The reasons for selecting just these 42 children require special emphasis:

(*a*) Before the start of the experiment these children had been considered as well-nourished and healthy by the methods of the Survey (and incidentally had also remained so throughout the experimental period).

(*b*) Initially they all had hæmoglobin values above 13 gm. per cent., satisfactorily distributed over a range of 13·03 to 16·27 gm.

(*c*) Their average age was about 12 years (midway between 8 and 16 years).

(*d*) Their initial hæmoglobin figures formed part of the figures from which the normal standards in paper IV had been established. (The results, therefore, depend to some extent on whether the biphasic phenomenon holds for the parent population, for the methods in this paper are based on the assumption that the distribution is Gaussian.)

(*b*) *The Diet.*

The basal diet of these 42 children supplied more or less the following per child per day: calories 2481, protein 73 gm. (about half of which was animal protein), calcium 0·7 gm., and at least 16 mg. "available" iron.

In addition to this they received daily supplements for the 10-month period in the form of extra milk and cheese (supplying chiefly vitamins A and D, and the minerals calcium and phosphorus), together with orange (or tomato) juice and Marmite (supplying vitamins C and B respectively).

(*c*) *Comparison of Hæmoglobin Readings in the "Optimal" Group before and after Feeding Experiment (10 Months).*

TABLE II.

	Average Age (Years).	No. of Subjects.	Before.		After.	
			Mean.	Observed Range.	Mean.	Observed Range.
BOYS:						
8–12		11	14·1	13·2–15·2	14·0	13·5–15·0
13–16		7	14·1	13·0–15·3	14·1	13·5–15·0
8–16	11·2	18	14·1	13·0–15·3	14·1	13·5–15·0
GIRLS:						
8–12		5	14·9	14·0–15·3	15·0	14·8–15·3
13–16		19	14·7	13·4–16·3	14·6	13·5–16·2
8–16	13·2	24	14·7	13·4–16·3	14·7	13·5–16·2
COMBINED: 8–16	12·2	42	14·5	13·0–16·3	14·4	13·5–16·2

In the following table an interesting comparison is given which shows the favourable contrast between the normal hæmoglobin range established

from the bloods of the 441 "normal" individuals (paper IV) and the range found in the 42 individuals of this study fed on an optimal or near-optimal diet for 10 months.

(d) Comparison between Hb. Values of "Normal" and "Optimal" Groups.

TABLE III.

Sex and Age (Years).	Hæmoglobin Values (in gm. per cent.).					
	"NORMAL" GROUP.			"OPTIMAL" GROUP. After Feeding Experiment.		
	No.	Mean ± ($\sigma/\sqrt{N}$).	"Conservative Normal" Range (Mean ± σ).*	No.	Mean.	Observed Range.
BOYS:						
8–12	112	14·38–14·58	13·38–15·58	11	14·03	13·5–15·0
13–16	136	14·69–14·89	13·55–16·03	7	14·10	13·5–15·0
8–16	248	14·58–14·72	13·53–15·77	18	14·06	13·5–15·0
(Av. Age)	(12·5 years)			(11·6 years)		
GIRLS:						
8–12	123	14·12–14·32	13·03–15·42	5	14·98	14·75–15·25
13–16	70	14·52–14·74	13·57–15·69	19	14·64	13·75–16·25
8–16	193	14·30–14·44	13·20–15·54	24	14·71	13·75–16·25
(Av. Age)	(11·6 years)			(13·6 years)		
COMBINED:						
8–16	441	14·48–14·58	13·48–15·58	42	14·43	13·5–16·25
(Av. Age)	(12·2 years)			(12·6 years)		

* Theoretically there is one chance in six that any single observation will be greater than M + σ and one chance in six that it will be less than M − σ, and two-thirds of the observations should lie inside this range. Actually 69 per cent. of the readings of the boys and 78 per cent. of the readings of the girls of the Normal group lie inside this range, which may be considered a satisfactory finding.

It is evident from Table III that the hæmoglobin values of the "Normal" and "Optimal" groups compare very favourably. The reason for the slightly higher mean values in the girls of the "Optimal" group may perhaps be ascribed to the fact that they were on an average two years older than the girls of the "Normal" group; similarly, the boys of the "Normal" group were on an average 11 months older than the boys of the "Optimal" group. Most important is the close agreement noticed between the Mean ±σ range of the 441 "Normal" children and the observed range in the 42 children of the "Optimal" group at the close of the experiment.

(e) *Conclusions.*

The most important conclusion must be drawn from Table II. The agreement between the two sets of figures in this table is extraordinarily close, suggesting that there has been no change in the hæmoglobins of these 42 subjects on an improved diet.

If this is correct, then the obvious conclusion is that hæmoglobin figures *above* 13 gm. in healthy normally nourished Cape Peninsula school children between 8 and 16 years can probably be looked upon as part of the optimal range in contrast to figures between 11 and 13 gm. which are probably sub-optimal and which at the utmost can only be considered as still lying within possible healthy limits of normal.*

Summary.

This last paper deals with two important questions in regard to the interpretation of "Normal" hæmoglobin standards for children:

(*a*) Whether hæmoglobin values lying *between* 11 and 13 gm. (the lower range of possible healthy limits, according to paper IV) should be regarded as sub-optimal or not. It was felt that the possibility of a certain degree of iron deficiency in children whose hæmoglobin figures lay between 11 and 13 gm. could not be excluded and since it is claimed that the M.C.H.C. is a sensitive index of iron deficiency, an attempt was made to answer the question by the aid of the M.C.H.C. values of the bloods of such normal children whose hæmoglobins lay between 11 and 13 gm.

In view, however, of the definite association in this study of hæmoglobin figures between 11 and 13 gm. with low M.C.H.C. values (indicating iron deficiency), it seems as if hæmoglobin figures between 11 and 13 gm. should be looked upon as probably sub-optimal, although still lying within possible healthy limits.

(*b*) The second question is whether hæmoglobin figures *above* 13 gm. may be considered as optimal in the sense that they can probably not be raised by a better diet.

A small well-controlled experiment was conducted on 42 normal children who had hæmoglobins above 13 gm. and who were resident in an institution. For 10 months these children received daily supplements of protein, vitamins A, B, C, and D and the minerals calcium and phosphorus, through the provision of milk, cheese, fruit juice and Marmite in addition to their basic diet.

* MacFarlane and O'Brien *et al.* (1944) claim that the Haldane standard really represents 14·8 instead of the usual 13·8 gm. of Hb per 100 c.c. blood. If this is, or should later on be, accepted as correct, the figures in this paragraph will have to be revised accordingly before application in survey or clinical work.

It was found that hæmoglobin figures above 13 gm. could not be raised by an improved and satisfactory diet over a period of 10 months. In the light of this finding, therefore, hæmoglobin figures above 13 gm. should probably be looked upon as lying within the optimal range. The argument that hæmoglobins above 13 gm. cannot be considered as optimal because they can be raised by iron therapy of course no longer holds in view of the possible unphysiological stimulant action of iron discussed in paper III.

Apart from the blood aspects with which this paper primarily deals, brief reference, in parentheses, is also made to the findings in the children at the end of the feeding experiment as regards the *nature* of their growth and the factors influencing their nutritional status, in comparison to a control group.

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A METHOD FOR ESTIMATING THE NUMBER OF RANDOM GROUPS OF ADJACENT DISEASED PLANTS IN A HOMOGENEOUS FIELD.

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The way diseased plants are distributed over an area is often a clue to the nature of the disease. If the disease is infectious and if the infection spreads readily from a plant to its neighbours, there is a tendency for diseased plants to be grouped together; while diseases which do not spread infectiously tend to attack plants randomly over a homogeneous area. The problem which arises is to determine whether the observed association of diseased plants in a field accords with an hypothesis of random distribution, or whether the amount of grouping is more than can be expected from chance association.

Various methods have been developed to solve this problem, but they are either incomplete or tedious to apply. The method which is given here is highly efficient, but at the same time so simple that calculations can be made directly in the field, often with nothing more difficult than a little mental arithmetic. Its simplicity will, it is hoped, lead to greater attention to the analysis of the areal distribution of plant disease, which has hitherto been handicapped by lack of a suitable method.

Three methods have been described which call for special comment: (1) a binomial series test (Cochran, 1936); (2) a geometric series test (Cochran, *l.c.*); and (3) a method for trees planted at the corners of a square lattice in a rectangular plantation (Todd, 1940).

(1) In the binomial series test the area may be divided arbitrarily into small plots, each containing, for example, 9 plants in 3 rows of 3 plants each. These plots may then be classed according to whether they contain 0, 1, . . . 9 diseased plants, and the observed number of plots in any class compared with the number expected for a binomial series. In general, if the disease is infectious and there is a tendency for it to spread to neighbouring plants, the observed series will differ from the binomial series in having too many plots with extreme numbers of diseased plants and too few with numbers about the mean; and discrepancies between the series may be detected with the χ^2 test.

The binomial series test is not very apt. It is sensitive to any sort of heterogeneity in the field which may be quite unconnected with the spread of infection from plant to plant; while at the same time it fails to use all the available evidence about the grouping of diseased plants. To use an illustration of Cochran's, if × represents a diseased plant and · a healthy one, the two configurations · × ×·×·× and ··× × × ×· would count as the same in the binomial series test (if lying in the same plot), although the latter contains more evidence of spreading from neighbour to neighbour. What one needs is a test which takes into account runs of diseased plants.

(2) Cochran's geometric series test is a modification and development of a method which had been used by Marbe to examine runs of births of the same sex in records of vital statistics, runs of heads and tails in tosses of a coin, and runs of red and black in roulette. In a long row containing diseased plants distributed at random, Cochran's expression for the number of runs of r diseased plants is

$$f_r = \mathrm{N}q(1-q)^{r-1}, \qquad r = 1, 2, \ldots$$

in which N is the total number of runs of all lengths and q the observed proportion of healthy plants. Departure from randomness can be detected by comparing the observed with the expected frequencies of runs of various length, and Cochran worked out a method of maximum likelihood to test the significance of the departure.

Cochran's was the first successful attempt to use runs as a measure of the extent of grouping of diseased plants in a row, but the method is tedious to apply.

(3) In his method for rectangular plantations Todd determined the number of two adjacent diseased plants, or "doublets", a term which we may conveniently retain. A doublet is different from a run of 2, which is 2 adjacent diseased plants bounded on each side in the row by a healthy plant. A doublet is 2 adjacent diseased plants without reference to the health of the plants which precede or follow it. All larger groups are reducible in terms of doublets; a run of 3 adjacent diseased plants is 2 doublets, a run of 4 is 3 doublets, and so on. Thus the determination of doublets has the great convenience that it gives in one single figure information on runs of all lengths from 2 upwards; it retains the value of using runs as a measure of neighbour-to-neighbour infection, but avoids dispersing the information over a large number of figures.

With trees planted at the corners of a square lattice in a homogeneous rectangular plantation l_1 trees long and l_2 trees broad (giving a total of $l_1 l_2$ trees), Todd estimated the number of doublets as

$$d = \mu(\mu - 1) \times \frac{4l_1l_2 - 3(l_1 + l_2) + 2}{l_1l_2(l_1l_2 - 1)},$$

where μ is the total number of infected trees in the plantation. In this estimate the diseased trees are assumed to be randomly scattered, and doublets are determined in every direction—that is, along the rows running the length of the plantation, along the rows running the breadth of the plantation, and diagonally.

Todd was also able to estimate the number of groups of 3 adjacent diseased plants ("triplets") and 4 ("quadruplets").

Todd's method has two limitations: it is restricted to crops planted in a regular rectangular system, with definite rows and equal spacing in the rows. Such crops are in the minority. Many crops are planted in rows but without equal spacing in the row. Some others are not even in rows but are sown broadcast, *e.g.* wheat. A second limitation—a minor one as we shall see—is that Todd's method cannot easily be extended to all sizes of groups of adjacent diseased plants; Todd did not go beyond groups of four.

The Number of Doublets in a Sequence of Plants in a Homogeneous Area.

Consider the examination of a sequence of plants in a homogeneous area. By sequence is meant any succession of plants, without restriction as to length, direction, spacing between plants, etc. The sequence could be a long row; or two or more rows, the last plant examined in the one and the first in the next being considered adjacent; or any succession of plants examined while proceeding through a field in any direction. If a total of n plants is examined in sequence, the number of pairs of adjacent plants (healthy and diseased considered together) is $n-1$, while the total number of pairs, adjacent or not, is $\frac{1}{2}n(n-1)$. The probability that a random pair shall be adjacent is therefore

$$p=\frac{n-1}{\frac{1}{2}n(n-1)}=\frac{2}{n}.$$

If out of the total of n plants μ plants are diseased, the number of pairs (adjacent or not) of diseased plants is $\frac{1}{2}\mu(\mu-1)$; and if the disease is randomly scattered the expected number of pairs of adjacent diseased plants, *i.e.* doublets, is

$$\begin{aligned} d &= \tfrac{1}{2}\mu(\mu-1)p \\ &= \frac{1}{n}\mu(\mu-1). \end{aligned}$$

One may consider the distribution of doublets to be binomial, which gives the standard error of d as $\sqrt{d(1-p)}$. Since $p=\frac{2}{n}$, one may with high values of n neglect p and consider the distribution of doublets to be

of the Poisson form, giving d a standard error of $\sqrt{d}$. It might be pointed out here that the closeness of the distribution to the Poisson form is independent of the proportion of plants infected, and depends only on the total number of plants examined. This case is somewhat unusual.

As in Todd's method, all higher groups of adjacent diseased plants are included in the determination of the number of doublets, a run of 3 adjacent diseased plants being 2 doublets, and so on.

As an example we may use Bald's (1937) data for the amount of infection by spotted wilt in tomatoes (variety Burwood Prize, block 2, examined 21st November, in Bald's Table 4, p. 24). The total number of plants examined, n, was 360 (made up of 12 rows of 30 plants each, the rows being considered to be joined end to end in one long sequence), and the number infected, μ, was 173. The expected number of doublets, if the disease is randomly scattered, is $\frac{173 \times 172}{360}$, which is 82·7, the standard error of this estimate being $\sqrt{82 \cdot 7}$ or $\pm 9 \cdot 1$. The number of doublets actually observed in the field was 81 (made up of 24 runs of 2, 9 runs of 3, 5 runs of 4, 2 runs of 5, 2 runs of 6, and 1 run of 7 adjacent diseased plants). There is thus no evidence in this result of any spread of infection from neighbour to neighbour, a conclusion which Bald also reached by using Cochran's methods.

General Method for Groups of any Number of Adjacent Diseased Plants in Sequence.

The method used for pairs of adjacent diseased plants—doublets—can be extended to groups of any number m of diseased plants. The possible number of groups of m adjacent plants in a sequence of n plants is $n-m+1$, while the total number of groups, adjacent or not, is $\frac{1}{m!}n(n-1)\ .\ .\ .\ (n-m+1)$. The probability that m plants at random shall be adjacent is therefore

$$p = \frac{n-m+1}{\frac{1}{m!}n(n-1)\ .\ .\ .\ (n-m+1)}$$

$$= \frac{m!}{n(n-1)\ .\ .\ .\ (n-m+2)}.$$

Out of the total of n plants suppose μ to be diseased. The number of groups of m diseased plants, adjacent or not, is $\frac{1}{m!}\mu(\mu-1)\ .\ .\ .\ (\mu-m+1)$.

Of this the fraction p consists of adjacent plants. The number of groups of m adjacent diseased plants is therefore

$$f_m = \frac{\mu(\mu-1)\ .\ .\ .\ (\mu-m+1)}{n(n-1)\ .\ .\ .\ (n-m+2)}, \qquad m=2, 3, \ .\ .\ .\ .$$

The distribution can be considered binomial, the standard error of f_m being $\sqrt{f_m(1-p)}$. With high values of n, p may be neglected; the distribution can then be considered to be of the Poisson form and f_m given a standard error of $\sqrt{f_m}$.

Just as all runs of three or more adjacent diseased plants are reducible to doublets, so all runs of more than m adjacent diseased plants are reducible to groups of m, a run of $m+a$ adjacent diseased plants being taken as $a+1$ groups of m.

The question arises whether it is useful to make use of groups larger than doublets. The answer seems to be that in most instances it is not. The fact is that the numbers of groups of different sizes, from doublets upwards, are not independent of one another. In the doublet system all higher groups are reduced to doublets, and in the number of doublets one has a composite index of the tendency towards grouping. The use of higher groups would therefore seem superfluous.

It has already been remarked that, because the use of doublets requires the calculation of only one figure, the method has a great advantage over a system of using runs. This advantage can be traced to the fact that the system of using runs is complicated by what, for our purpose, is an irrelevancy: the positional relation of diseased to healthy plants. This relation is implicit in the definition of a run as a number of adjacent diseased plants with a healthy plant on each side. The doublet method takes into account only the relation of diseased plants to one another, which is what one wants to know. Herein lies its simplicity and efficacy.

The interdependence of groups of various sizes may be illustrated by an example. In Table I is given an analysis of some unpublished observations by Ledeboer on the distribution of gummosis disease of the black wattle (*Acacia mollissima* Willd.) in a plantation near Pietermaritzburg. Two hundred trees were examined and of these 93 showed gummosis ($n=200$, $\mu=93$). The observed number of groups ranging in size from two adjacent diseased trees (*i.e.* doublets) to eight is compared with the expected number f_m calculated by the equation already given.

The inter-relation of the various estimates is shown by the fact that in every instance the observed and expected values differ by less—far less—than the standard error. Were the estimates for the different groups independent, such a result would be highly improbable. The calculation of estimates for all the various groups gives an emphasis to the agreement

TABLE I.

Gummosis Disease of the Wattle; the Number of Groups of m *Adjacent Diseased Trees. (Ledeboer's Data.)*

m.	Observed number.	Expected number.	Standard error.
			±
2	46	42·8	6·5
3	21	19·6	4·4
4	8	8·9	3·0
5	4	4·0	2·0
6	2	1·8	1·3
7	1	0·80	0·90
8	0	0·36	0·60

which is quite misleading. Actually, all the evidence one has about the randomness of the grouping is given by a comparison of the observed and expected number of doublets, 46 and $42{\cdot}8 \pm 6{\cdot}4$. Calculations for larger groups repeat information already given by doublets, but give less of it; and they should be made only when they are specifically wanted, or when some abnormality of grouping is suspected.

Summing the Results of Different Sets of Observations.

The method which has been discussed is applicable only to a homogeneous area, and does not hold when uniformity is lacking. To give a crude illustration, diseases caused by waterlogging tend to occur at the bottom of a sloping field, and there may be excessive grouping there of diseased plants about one another even when infectious spreading is absent. A test for the uneven distribution of disease over an area has been devised by Cochran (*l.c.*); but our interest is more in the other side of the picture: we are concerned not so much with a test for heterogeneity, but with how to avoid heterogeneity if it does occur. For this purpose one may use the fact that the sum of several components, each of which is independently distributed in a Poisson series, is itself so distributed. The whole area is divided into a number of small, compact blocks, each of which is nearly uniform, as judged by tests appropriate to the circumstances. Counts of doublets are then made in each block, summed, and compared with the estimated number of doublets, which is likewise obtained as the sum of the estimates for each of the blocks. Clearly, the smaller the block, the less is the chance of its being uneven. But the size to which the block can be reduced is limited by the condition that the distribution must belong to the

Poisson series. That condition, it has already been pointed out, is fulfilled when the total number of plants examined, n, is large. In ordinary circumstances it is probably sufficient not to reduce the number of plants in a block below 100; at this point the error in the form of the distribution is practically negligible. For very uneven fields smaller blocks might be used at the expense of incurring a larger error in the form of the distribution (or of changing the method of approach and judging the significance of deviations of observed from estimated values by means of the χ^2 test); while in uniform areas with closely planted crops we have successfully used blocks containing 1000 or more plants without incurring any appreciable error from areal gradients of disease. The matter is one for judgment on the spot.

The same procedure of summing is useful when dealing with a large number of scattered observations, such as are commonly found in a plant pathologist's note-book. We may illustrate the method with records for Kromnek disease (spotted wilt) of tobacco, caused by *Lycopersicum* Virus 3 K.M.S. Observations were made over the three years 1941 to 1913, inclusive; at Pretoria, at Buffelspoort (in the Rustenburg district), in the Brits district, and (mostly in collaboration with Mr. E. E. Anderssen whose help is gratefully acknowledged) at Hartebeespoort Experiment Station (at Brits); and on many varieties. In all, there were 29 sets of observations, representing a total of 10,294 plants examined. Results are given in Table II.

The estimated total number of doublets, obtained by summing the estimates for each set of observations, is 173·9, to which we assign a standard error of $\sqrt{173{\cdot}9}$ or $\pm 13{\cdot}2$. The observed number was 177, an excess of 3·1 over the estimated number, which is well within the limits of error. One may regard this excess as that portion of the total number of diseased plants, 1067, which could have been infected by their immediate neighbours; and there is in the sum of all the observations enough evidence not only for a negative demonstration of lack of significant departure from randomness, but also for the positive assertion that neighbour-to-neighbour infection occurs only to a trifling extent, if it occurs at all.

It might be interpolated here that when the total number of doublets is large, as in the previous example, one may use the conventional criterion that deviations of observed from estimated values may be considered significant if they are twice the standard error, or more. But when the estimated number of doublets is small, one must allow for the skewness of the distribution and judge the significance of deviations by reference to the exact distribution which has been tabulated in Tables for Statisticians and Biometricians and elsewhere. The same applies to larger groups of adjacent diseased plants than doublets, with even more force because these are usually relatively few in number (*cf.* Table I).

TABLE II.

Kromnek Disease of Tobacco. Sets of Observations recording the Total Number of Plants examined n ; *the Number Infected* μ ; *and the Observed and the Estimated Number of Doublets* d.

Place.	Date.	Variety.	n.	μ.	d (obs.).	d (est.).
H'poort Expt. Station	Nov. '41	Amarelo	356	33	2	3·0
,, ,, ,,	,,	,,	240	28	4	3·1
,, ,, ,,	,,	,,	156	8	0	0·4
Pretoria . . .	,,	,,	131	12	1	1·0
,, . . .	,,	,,	119	12	0	1·1
,, . . .	,,	,,	157	5	0	0·1
H'poort Expt. Station	Dec. '41	,,	480	18	1	0·6
Brits . . .	,,	,,	200	28	2	3·8
,, . . .	,,	,,	275	98	35	34·5
,, . . .	,,	,,	80	25	5	7·5
Buffelspoort . .	Jan. '42	,,	1305	81	8	5·0
,, . . .	,,	,,	456	32	1	2·1
,, . . .	,,	,,	114	7	1	0·4
H'poort Expt. Station	Nov. '42	,,	763	15	0	0·3
,, ,, ,,	,,	,,	272	12	0	0·5
,, ,, ,,	,,	Joiner	95	15	0	2·2
,, ,, ,,	,,	P. R. Swazi	539	15	0	0·4
,, ,, ,,	,,	,,	425	16	0	0·6
,, ,, ,,	,,	,,	203	6	0	0·1
,, ,, ,,	,,	W. D. Nyassa	554	26	2	1·1
,, ,, ,,	Dec. '42	Groot Swazi	232	28	2	3·3
,, ,, ,,	,,	,,	461	61	11	7·9
,, ,, ,,	,,	,,	132	25	4	4·6
,, ,, ,,	Nov. '43	Amerelo	442	87	22	16·9
,, ,, ,,	,,	,,	471	124	31	32·4
,, ,, ,,	,,	,,	357	43	9	5·1
,, ,, ,,	Dec. '43	P. R. Swazi	500	68	6	9·1
,, ,, ,,	,,	,,	536	115	27	24·5
,, ,, ,,	,,	Waterberg	243	24	3	2·3
			10294	1067	177	173·9

In the case of plantations set out in a regular rectangular system, one may analyse the rows up and down in one direction, then in the other direction, then diagonally, and sum the results. This procedure has the advantage over Todd's (*l.c.*) because it is not affected by odd trees missing here and there, and because it shows whether there is a difference in grouping between the various directions.

SUMMARY.

The problem was to determine whether the amount of grouping of diseased plants over an area was consistent with an hypothesis of random scattering, which would occur only if the disease did not spread infectiously from neighbour to neighbour.

If n plants are examined in sequence over a uniform area and if, of these, μ are diseased, the number of random groups of two adjacent diseased plants ("doublets") is given by the expression $d = \frac{1}{n}\mu(\mu-1)$. The term, doublet, is taken to mean any group of two adjacent diseased plants; all higher groups are reduced to doublets, a run of three adjacent diseased plants being two doublets, and so on. The distribution belongs to the binomial series, and to d is assigned a standard error of $\sqrt{d(1-p)}$, in which $p = \frac{2}{n}$. For high values of n the distribution approaches the Poisson form, d having a standard error of $\sqrt{d}$.

The method can be extended to groups of any size, although the use of groups larger than doublets is not as a rule necessary. The number of groups of m adjacent diseased plants is

$$f_m = \frac{\mu(\mu-1)\ .\ .\ .\ (\mu-m+1)}{n(n-1)\ .\ .\ .\ (n-m+2)}, \qquad m = 2, 3, \ .\ .\ .$$

in which n and μ have the same meaning as before. All larger groups are reduced to groups of m, a run of $m+a$ adjacent diseased plants being taken as $a+1$ groups of m. To f_m one assigns a standard error of $\sqrt{f_m(1-p)}$ in which $p = \frac{m!}{n(n-1)\ .\ .\ .\ (n-m+2)}$; for large values of n the standard error reduces simply to $\sqrt{f_m}$.

In practice, it is advisable to avoid areal gradients of disease by dividing the field into reasonably small compact blocks, and applying the method separately to each. Provided that the blocks are not so small that the distribution of doublets departs greatly from the Poisson form, a result for the whole area may be reached simply by summing, a procedure also applicable to gathering together scattered sets of observations. As an example, an analysis is made of records of Kromnek disease of tobacco, caused by *Lycopersicum* Virus 3 K.M.S., which is shown not to spread infectiously from neighbour to neighbour.

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A NEUTRAL SOLUTION OF FORMALDEHYDE FOR BIOLOGICAL PURPOSES.

By J. L. B. Smith.

(Read September 20, 1944.)

The advantages of aqueous formaldehyde as a preservative of animal and vegetable structures are so well known as to require no repetition here. At the same time this preservative has certain disadvantages, chief of which are the result of its chemical nature. Like all aldehydes, formaldehyde absorbs oxygen comparatively readily even from the air and is thereby oxidised to formic acid. Solutions of formaldehyde attain fairly rapidly and maintain a pH of 3·5 or even of 3. When a zoological specimen, such as a fish, is immersed in this acid solution a relatively complex series of chemical changes occur which weaken the solution and damage or impair the structure. Protein and protein-degradation products neutralise a surprising amount of acid in a solution more acidic than pH 4. Experiment has shown that 100 gm. of fish flesh will during two years neutralise close on 8 ml. of normal formic acid. Also calcified and ossified structures are decalcified in acid sòlution. These changes continue until decalcification is complete or until all the formaldehyde has been oxidised. This renders the use of acidic formaldehyde solution over long periods for even robust specimens undesirable, and entirely prevents its employment in that condition for more delicate structures with light ossifications or calcifications which it may be desired to preserve unimpaired. Further, acid conditions favour the formation of solid polymers of formaldehyde which, alone or mixed with calcium phosphate, are often deposited on, and adhere most tenaciously to, immersed specimens, sometimes so extensively as completely to cover and hide structural features. The removal of this deposit is often impossible without very serious impairment of the material.

Since neutral or very slightly alkaline solutions of formaldehyde are free from these disadvantages, the obvious solution of this difficulty is to remove the acid by neutralisation, but agents which produce too high a pH (*i.e.* too high a degree of alkalinity) are unsuitable, since the formaldehyde may under those conditions be destroyed by undergoing self-condensation to substances of little or no preservative value. The ideal would be a buffering method whereby the solution may be maintained as nearly as

possible at neutrality, *i.e.* pH 7, or only slightly alkaline, say pH 7–8. No information about antoxidants for formaldehyde is available.

Various buffering materials for formaldehyde solutions have already been proposed. Carbonates and bicarbonates of various metals have been suggested, but Atkins (J. Mar. Biol. Ass., N.S., 1922, xii, p. 792) has shown that all are unsatisfactory, *e.g.* he states that formalin distilled with solid $MgCO_3$ gives a distillate of pH 4·4. Also carbonate neutralisation involves the more or less continual evolution of carbon dioxide, which may be a very serious disadvantage, while formaldehyde solutions neutralised by a strong alkali apparently re-oxidise with great ease.

Atkins (*loc. cit.*) has suggested the use of borax, in such amount (5–10 gm. per litre) as to produce a solution of pH 8·5–9·0. This is apparently the most satisfactory method hitherto proposed and has been widely adopted. The method involves the use of indicators to show whether the desired pH has been attained. It suffers from the further disadvantage that for the buffering to be automatic over a long period, so much borax must be added that the alkalinity of the solution is stepped up to a point where self-condensation of the aldehyde may become marked.

A solution with a tendency to acidity due to autoxidation such as that of formaldehyde may be buffered near neutrality either by thus adding the salt of a weak acid and a strong inorganic base such as borax, or by the addition of excess of a very weak base. No suitable soluble inorganic bases are available. Amongst organic bases the choice is limited to those soluble in water, and still further to those whose presence in a preserving medium would not be undesirable. One such is hexamethylenetetramine (or hexamine) which results from the interaction of formaldehyde and ammonia as follows:—

$$6CH_2O + 4NH_3 = (CH_2)_6N_4 + 6H_2O.$$

It is crystalline, and easily soluble in water, giving a feebly basic solution (pH 7·6–8·0 over a wide range of concentrations).

Its addition in moderate amount to an old formaldehyde solution of pH 3 alters that immediately to pH 7·6–7·8 by the basic character of the hexamine alone. Experiments covering five years have shown that formaldehyde solutions over a wide range of concentrations may be maintained at pH 7·0–7·8 by the addition of hexamine. It seems likely from observations made that autoxidation of the formaldehyde in the presence of hexamine at this pH range is less than normal, *i.e.* that it functions not only as a weak base but also as an antoxidant.

Hexamine is in normal times available in quantity and relatively inexpensive, and proves to be an excellent buffering agent for formaldehyde solutions. These may be maintained so slightly alkaline that polymerisation does not occur and decalcification of material is not possible.

Professor J. Omer-Cooper of this College has tested formaldehyde solutions so prepared for use with histological material, and has reported them to be satisfactory for even the most delicate structures. For the preservation of fishes the solution has been found excellent, and specimens are beautifully preserved with no trace of surface deposit.

In preparing fresh solutions of buffered formaldehyde it is recommended for ordinary purposes that 200 gm. hexamine be added to each litre of formalin solution, *i.e.* 2 lbs. hexamine to 1 gallon formalin. (By formalin is meant 38–40 per cent. formaldehyde solution.) This solution may be diluted as desired. Solutions prepared in this fashion are at about pH 7·8.

If hexamine be unobtainable, the same result may be achieved by the addition of ammonia, with, however, considerable effective loss of formaldehyde since hexamine is formed from it. Concentrated ammonia solution S.G. 0·9 may be employed. It should not be added direct to the concentrated formaldehyde solution as the reaction is too violent. The formalin should first be diluted, and the ammonia then added with caution and constant stirring for the stronger solutions.

The following table shows the quantities recommended:—

Per cent. Formaldehyde desired:	3	4	6	8
38/40 Formalin vol., litres:	1	1	1	1
Add Water, litres:	$6\frac{1}{2}$	6	5	3
Stir in 0·9 S.G. Ammonia:	200 ml.	150 ml.	125 ml.	100 ml.

Estimations made with solutions of considerable age prepared by either method indicate that if kept in fairly good containers, with average handling and exposure to air, they should maintain both strength and practical neutrality for many years.

For special purposes solutions almost exactly neutral may be prepared. For this purpose add 3 per cent. hexamine by weight to the diluted solution and mix thoroughly. Remove 50 ml. and titrate with a normal solution of formic acid (5 ml. pure formic acid diluted to 100 ml.), using a suitable internal indicator (B.D.H. Universal is satisfactory), until the desired pH in the range 6·8–7·2 is attained. The amount of formic acid to be added to the main known bulk of the solution may then be calculated.

In treating old dilute solutions of formaldehyde, they should be transferred to some large vessel and well mixed. Add with stirring 10 ml. 0·9 S.G. ammonia diluted to 50 ml. for each litre of solution. The solution will on an average then be about pH 7. (Litmus test paper or an external indicator may be used if desired, but is not essential.) Then add 15 gm. hexamine for each litre of solution and mix well. For ordinary Museum purposes it is as effective merely to add 30 gm. (1 oz.) hexamine for each

litre of dilute formaldehyde solution. In these latter cases it is as well to add some fresh formalin to replace that lost by oxidation.

It may be noted that hexamine neutralises acids, beyond its feebly basic nature, also by reacting with them to produce formaldehyde, as follows:—

$$(CH_2)_6N_4 + 2H_2O + 4H_3O^+ = 6CH_2O + 4NH_4^+ \qquad (1)$$

In concentrated solutions at the ordinary temperature this reaction is reversible at pH 4–5, *i.e.* formaldehyde solutions react with ammonium salts to give an acid solution of pH 4–5. In concentrated neutral solutions of formaldehyde therefore reaction (1) plays no part in maintaining neutrality. In more dilute solutions of formaldehyde, however, low concentrations of ammonium salts appear unable to render the solutions acidic. From observations on solutions kept for over four years, it appears that in dilute formaldehyde solutions hexamine gradually destroys acidic conditions up to pH 6 by reaction (1). In such solutions therefore hexamine likely maintains relative neutrality by threefold action—as a base, as an antoxidant, and by removal of acid according to reaction (1). It will in that event not only maintain neutrality but also replace any formaldehyde lost by oxidation.

I wish to express my gratitude to the National Research Board of South Africa for a grant which defrayed part of the costs of this investigation.

Rhodes University College,
Grahamstown,
September 1944.

THE EVOLUTION OF MIDDLE PALAEOLITHIC TECHNIQUE AT GEELHOUT, NEAR KAREEDOUW, IN THE SOUTHERN CAPE.

By P. W. LAIDLER, F.S.A.(Scot.).

(With ten Text-figures.)

(Read May 15, 1940.*)

CONTENTS.

COLLECTIONS TO WHICH REFERENCE IS MADE IN THE TEXT:

P. Pretoria Museum Collection.

J. Dr. Jeppe's Collection.

P. W. L. The Writer's Collection, now in part at Witwatersrand University. A small chosen series of Geelhout material is exhibited in the East London Museum. The mass has been presented to the Albany Museum, Grahamstown.

Alb. Albany Museum, Grahamstown.

SECTION I. THE KAREEDOUW GRAVELS: GEOGRAPHICAL POSITION AND ARCHAEOLOGY.

West of Humansdorp, on the Long Kloof road beyond Kareedouw, are extensive gravel deposits on terraces which extend for some miles between the mountains (text-fig. 1). Their maximum depth is about 2 feet, and they overlie the solid rock or a hard red clay. In places the gravels are covered with alluvium. The gravel is divided into two distinct zones, the lower coarse and slightly boulder-like and the upper of smaller size, in which latter fairly crude artefacts occur. They include hand-axes (*coups de poing*) made on flakes which vary from 12·5 to 25·5 cm. in length, cleavers of large and medium size, to many of which lateritic material adheres. They have few negative facets, and the majority are not much

* Revised June 1945.

smaller in overall dimensions than the initial flake from which they are formed. The assemblage also contains discs:

A. 12·5 cm. in diameter and 5 cm. thick, formed from outer flakes of boulders, the outer or cortex face being worked down only around the periphery, and leaving an area of cortex.

B. biface discs 11·5 cm. in diameter and 6·3 cm. thick with sinuous, clean, and unbattered edge.

Lying on the gravel and at the base of the alluvium a typical Middle Stone Age (faceted-butt) unworked point was found. The alluvium and the upper twelve centimetres of gravel contain Middle Stone Age flakes in fresh quartzite. The alluvium is free from hand axes and cleavers. The artefacts found are divisible into three distinct phases:

1. Stellenbosch, large (unfinished) hand axes and smaller of 17·8 × 6·4 cm. which are weathered, not rolled.
2. A later phase of Stellenbosch or Fauresmith, mixed with Middle Stone Age type artefacts and flakes referable to the primary flaking of a hand-axe industry.
3. A Middle Stone Age industry of uncertain phase, but of much later date than 1 and 2.

Section II. The Geelhout Eroded Area: Geographical Position.

Twenty miles nearer the coast, at the farm Geelhoutboom, is an extensive eroded area, about two miles long by three-quarters of a mile broad, on a low ridge parallel with the coast and about a mile distant from it, the relative position of which is indicated in text-fig. 1, B—a diagrammatic sketch of the area and the various sites. The farm has been occupied for three generations by the same family and erosion is stated to have commenced about eighty years ago. The ridge rises steeply on the land side of a vlei and slopes slowly to the south-east or sea side. Its greatest height is about 150 feet above the level of the vlei. It consists of aeolian sands, the older consolidated, the recent wind-blown. East of the ridge the Tsitsikamma River flows in a deep chasm. There is, however, a cross slope away from this; the storm water from the ridge drains into the vlei and flows westward to the sea, encircling the ridge. No geological terracing is distinguishable along this portion of the Tsitsikamma River, and the general level of the land into which its bed is eroded is that of the base of the Geelhout ridge. It is almost an island, magnificently protected by sea, chasm, and marsh, and attracted prehistoric man as a suitable area for settlement.

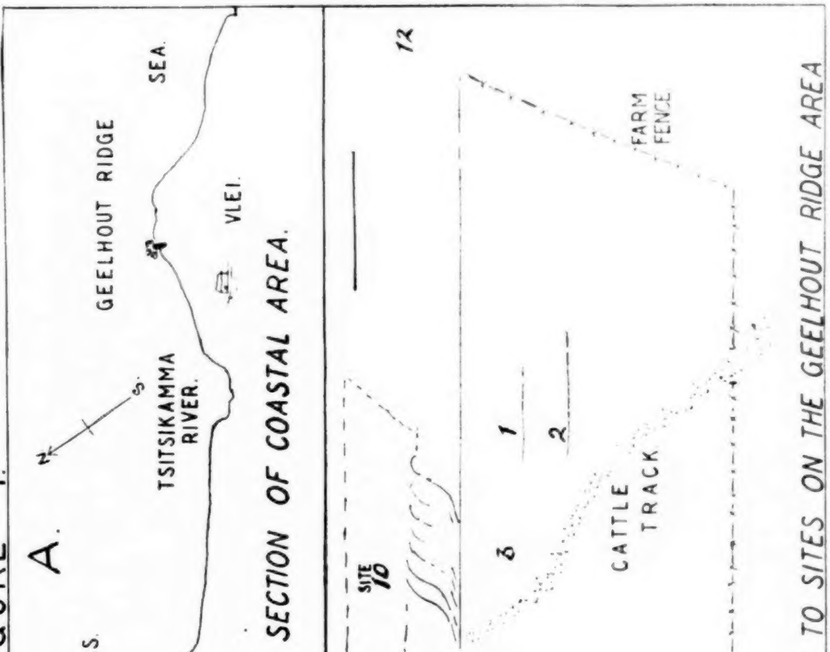

FIG. 1.—A. Diagrammatic vertical section of coastal area in vicinity of Kareedouw. B. Key to sites described.

Section III. Surface Geology of the Geelhout Area.

There is a tendency for all strata on the land side of the ridge to weather into sloping terraces of hard red loess, the more freshly exposed of which show a layer of hard-pan. On the summit is an exposure of decomposed sandstone boulders, suggesting that the ridge has a core of rock. Actually it is the smallest and last of the ranges which fall off in height from the Langebergen and the Tsitsikamma Mountains eastwards towards the sea (text-fig. 1, A). All pebbles and waterworn stones with which the later white aeolian sand and the exposed older red loess are covered have been carried thither by human agency. In several places, especially towards the south-east, erosion has provided sections through the red loess, showing that it is sterile for a depth of 20 feet at least. The loess terraces have been protected by a layer of hard-pan, suggesting a wet, following an erosive, period. The terraces have been considerably eroded during recent times by wind and rain. In several places between the hard-pan and the recent white aeolian sand there is a stratum of black sand 2 to 3 feet in depth, the result of a period of vegetative luxuriance.

This stratigraphy and that described below on other sites has been diagrammatically combined in text-fig. 10. There is no tilting of recent strata, while the distance and height of the ridge from the sea are great enough to suggest that no rise or fall in the land surface could have had any bearing upon its archaeology.

Section IV. The Archaeology of the Geelhout Area.

A. The general area collection is composed of implements found individually and not included in specifically collected sites. These include three types of hand-axe in which size is no criterion of age, and in which technique differs widely. There are:—

(i) The early biface hand-axe, somewhat round on section formed on a core produced by primary flaking from point and sides, and with the long and exaggerated points and with cylindrical butts. A small number was found only on the lower, eroded ground to the south-west, and all were half-embedded in the surface of the red sand or loess. Ovates, typical of the Upper Stellenbosch, occur of dimensions 15×10 and $7{\cdot}5 \times 6{\cdot}5$ cm.

(ii) Uniface hand-axes, formed on flakes, one showing clearly the bulb of percussion on the side, from $7{\cdot}5 \times 5$ to $12{\cdot}7 \times 7$ cm., which represent, according to the accepted definition, Tachengit phase. This class is not strongly represented. The implements are secondarily worked only where it has been necessary to reduce their thickness.

(iii) Thin flat, almond-shaped biface hand-axes of two types:

a. With rounded butts and long, slender and graceful straight-edged points, that is, kite-shaped (text-fig. 2, A).

b. With less lengthy points, rounded (not illustrated).

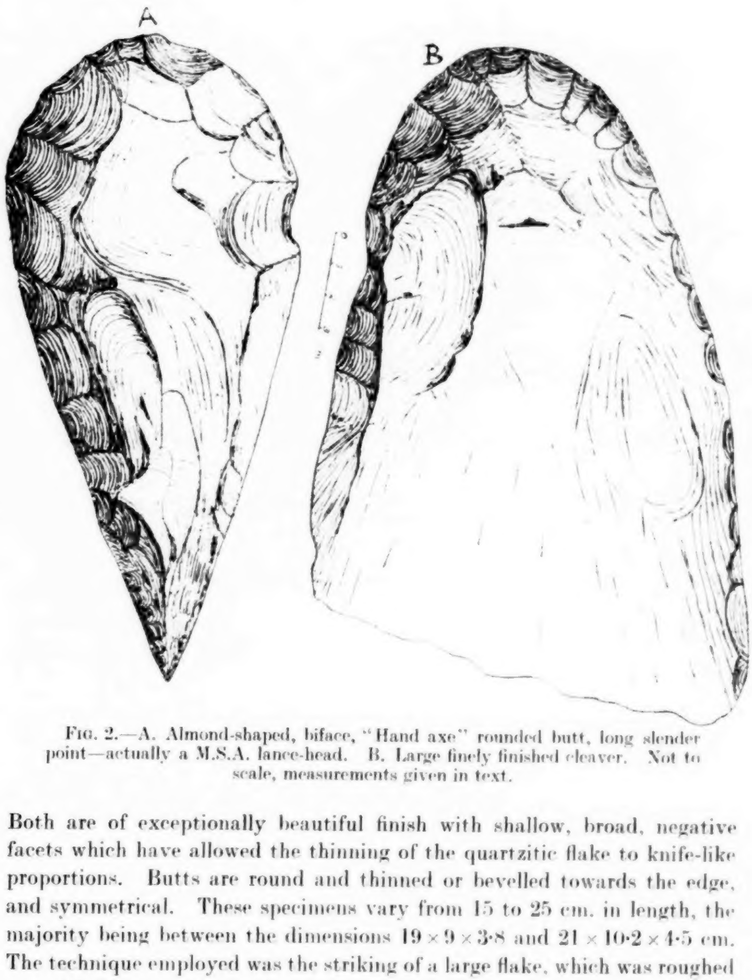

FIG. 2.—A. Almond-shaped, biface, "Hand axe" rounded butt, long slender point—actually a M.S.A. lance-head. B. Large finely finished cleaver. Not to scale, measurements given in text.

Both are of exceptionally beautiful finish with shallow, broad, negative facets which have allowed the thinning of the quartzitic flake to knife-like proportions. Butts are round and thinned or bevelled towards the edge, and symmetrical. These specimens vary from 15 to 25 cm. in length, the majority being between the dimensions $19 \times 9 \times 3{\cdot}8$ and $21 \times 10{\cdot}2 \times 4{\cdot}5$ cm. The technique employed was the striking of a large flake, which was roughed out with heavy primary blows from the point and trimmed by secondary blows which removed long, wide, and shallow flakes from over the whole

surface. The edge and point were finished by tertiary flaking, removing short almost square flakes of small size. A series of rejects and of finished implements suggests that the completed implement is little smaller in overall dimensions than the original flake from which it was made, but which has been thinned down.

Large cleavers, less common, but of equally fine finish also are found (text-fig. 2, B).

B. On the recently wind-eroded area were numerous distinct and separate occupation areas of small size (text-fig. 1) on which artefacts were concentrated in large numbers.

On the low terraces parallel with the vlei the sites produced Middle Stone Age artefacts, only occasional small hand-axes, and no Stellenbosch artefacts. These sites were collected from separately and are described individually.

Site 1.—This produced many Middle Stone Age flakes and unworked points with faceted butts, and a few points with resolved flaking on one edge and butt, which are distinctly separable from the Still Bay or any other recorded point. On the negative face the central rib is eccentric, and the base and broader side are secondarily trimmed, leaving one natural edge. These, being distinctive of this site, will be referred to as "Geelhout Points" (text-fig. 8). No hand-axes were found here. Only two small hand-axes (so tiny that the recognized term is as much a misnomer as it is for the third type of hand-axe in the general area collection).

Site 2.—This produced two medium-sized cleavers (text-fig. 3); several tiny ones; the predominating implements were plain points and blades; 9 oakleaf; Levallois-type points of large size, of which one is secondarily worked. Kasouga trimming occurs, that is, the negative facets of, in this case probably, percussion-flaking occur along the sides of the flake's surface (positive face); discs, double-faced, 2; 2 biface, fully faceted, type D.

Site 3.—Here the predominant features are serrated or oakleaf technique and Kasouga trim. One flake, 6 inches long and steeply trimmed by percussion, shows two long shallow negative facets, suggestive of pressure. Keeled, parellel-sided long flakes are worked on both edges. One large backed blade, and a pebble section cleaver with cortex left on the butt (text-fig. 3), that is, a small cleaver or tranchet type formed from a pebble flake struck from one side of a divided pebble with cortex on its butt only.

Site 4 is an extensive area below the prominent patch of bush. It produced, towards the east, large weathered hand-axes. On the main site, or western half, smaller and less weathered hand-axes, and Middle Stone Age material still less weathered. The Middle Stone Age material included one large weathered Levallois type point with flat single-facet butt; one Levallois type point; and small points with rounded butts, of

which 5 out of 15 show secondary resolved flaking. Kasouga trim is present on blades.

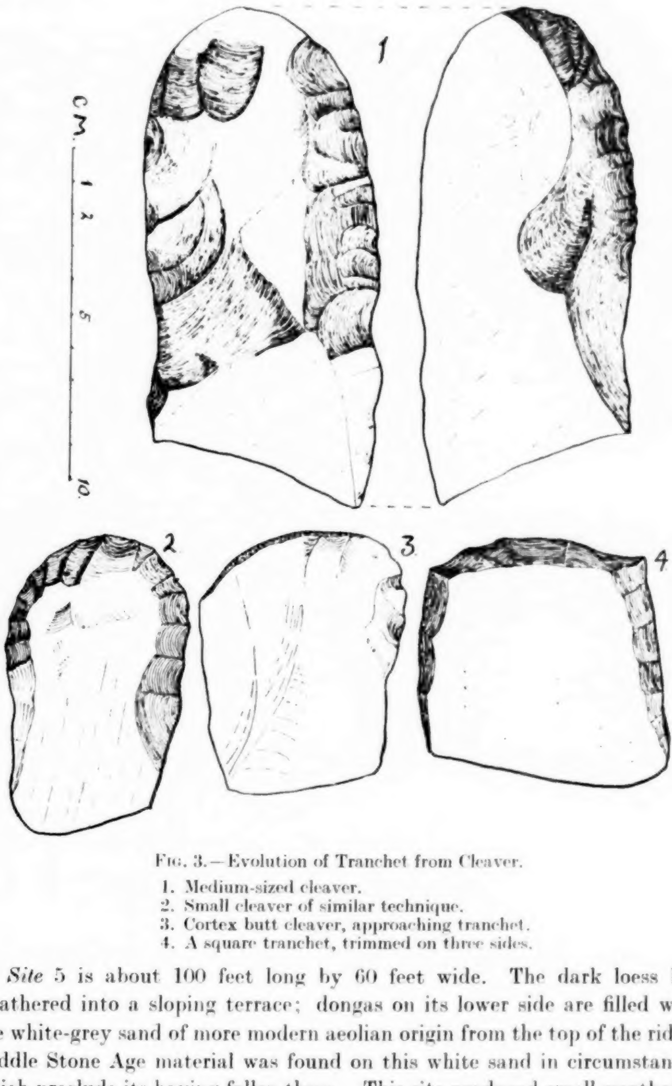

FIG. 3.—Evolution of Tranchet from Cleaver.

1. Medium-sized cleaver.
2. Small cleaver of similar technique.
3. Cortex butt cleaver, approaching tranchet.
4. A square tranchet, trimmed on three sides.

Site 5 is about 100 feet long by 60 feet wide. The dark loess has weathered into a sloping terrace; dongas on its lower side are filled with the white-grey sand of more modern aeolian origin from the top of the ridge. Middle Stone Age material was found on this white sand in circumstances which preclude its having fallen there. This site produced small weathered

hand-axes, and hand-points finely worked at the tip in the manner of Type III hand-axe; numbers of small triangular points and oakleaves, serrated points, 14; long parallel-sided serrated blades, 113; backed blades showing trimming at the point, a flake partly trimmed to form a large scraper, one high-bank point (Pietersburg type); two large end-scrapers and one concave scraper, at first thought to be possibly intrusive. The predominant feature of the site is percussion-trimmed small triangular points.

Site 6 is situated on the upper dune edge where active erosion has deposited Middle Stone Age implements from the bushy surface of the white sand dune upon the underlying hard surface.

The depth of the white aeolian sand here is small, and industry-succession is suggested by the hand-axes found on the hard surface (an old land surface?) which are all severely weathered. Large and small Middle Stone Age points occurred in considerable numbers and showed an equal standard of weathering of lesser degree than the hand-axes, while both large and small show Kasouga trim. One small point has the bulb trimmed away to produce a concave butt for shafting. One point is trimmed on alternate sides. Four points are carefully prepared by resolved flaking; four show long shallow negative facets. The pebble-section cleaver of small size is a definite member of the phase assemblage. The site also produced two undoubted end-scrapers, of which material and weathering suggests they are not intrusive.

Site 7 overlooks the Tsitsikamma River. It is 100 yards long by 30 feet wide. Small-sized triangular points predominate over medium, and serrated work predominates over resolved. Alternate edge trimming, that is Kasouga trim, is present, and one point with secondary resolved trimming and slightly hollowed butt. A square flake with faceted butt and opposite edge trimmed is an end-scraper (text-fig. 4, 7).

Some of the serrated or oakleaf points are more sand blasted than the resolved points, and the former do not have well-faceted butts, but a tendency to laminated shattering, to thin the butt. Further, they are often of a curved or scimitar shape, with a tendency to the negative facets of a Levallois technique. Serration and resolved flaking occur together on the same artefact. An assemblage of flakes from this site showed an average size below that of the remainder of the area.

A single typical Howieson's Poort crescent was found, also much sand-blasted, and one finely worked broken point.

End-scrapers numbered four, large and coarse, one possessing Kasouga trim on both edges of its positive or bulb of percussion surface, linking it with the other Middle Stone Age material of the site.

An addition to the assemblage is a circular quartzite, palette-like artefact.

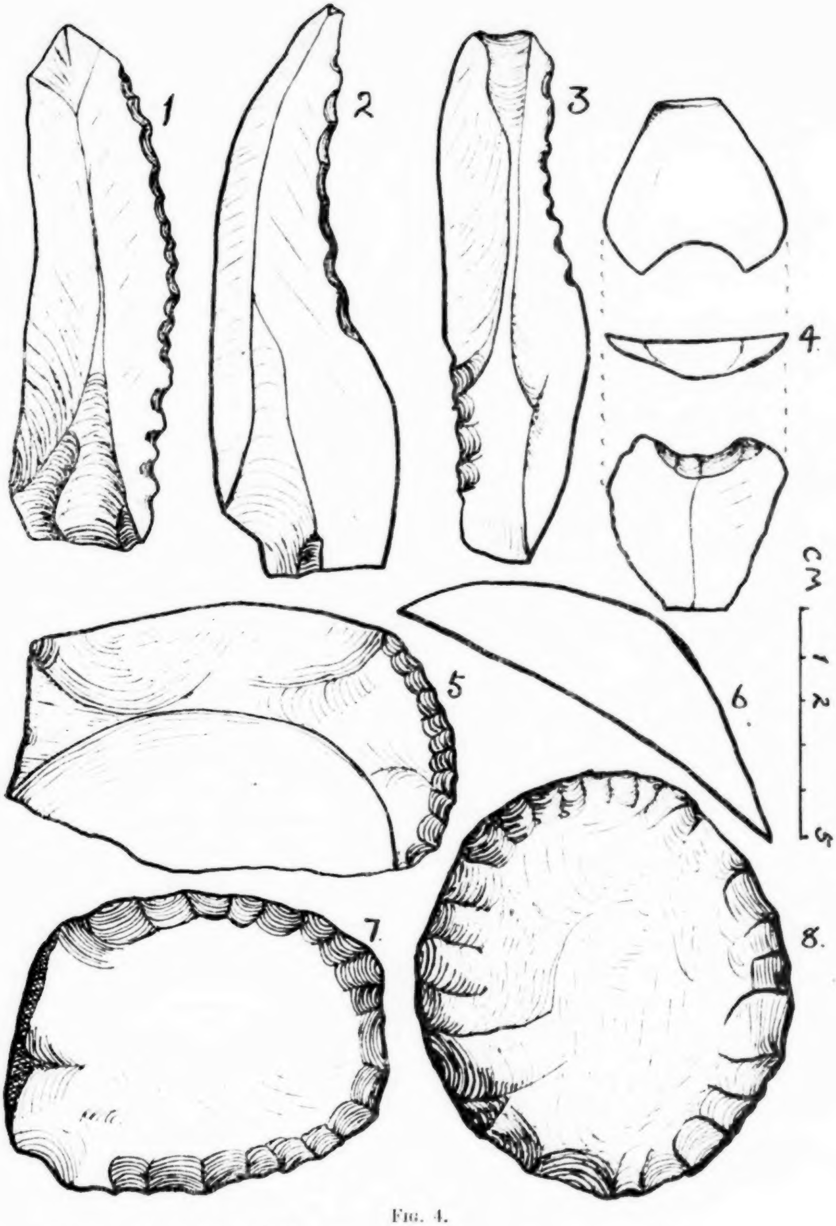

Fig. 4.

1. Scraper blade, faceted butt, convex side serrated.
2. Scraper blade, faceted butt, concave side serrated.
3. Scraper blade, double-sided, one concave, one convex.
4. Three views of an unusual concave scraper the convexity being worked on the blade opposite the butt.
5. An end scraper (giant thumb nail) faceted butt.
6. A circular scraper, uniface, worked on a large flake by resolved flaking. Section.
7. An end scraper on pebble section, with cortex butt, worked round three sides.
8. An almost circular scraper, percussion flaked round edge.

Site 8 is 60 feet long by 40 feet broad, and is situated on an extensive gentle slope, where there is no evidence of wash of implements from higher levels. On this site all earlier and large types of hand-axes and small artefacts are absent, and there is no flake with Kasouga trim. The feature is the serrated concave side-scraper which occurs here in greater numbers than elsewhere (text-fig. 5, 2 and 3). The assemblage is: one-sided serrated blades, 30; double-sided, 12; double concave, 1; single concave, 7; one backed blade; one core fabricator; 22 thick heavy quartzite points with flat, poorly faceted butts, deeply serrated, and including flat parallel-sided blades worked to a point, and high-back points. The whole of the material is coarse and its workmanship crude in appearance, though it was certainly capable of taking a better finish. The site produced only four triangular points with secondary work, and one point with shallow negative facets.

Site 9 is a widespread area of mixed ages. (Near by was a stone on which the worker sat, and around it was an accumulation of cores and flakes.) Here was found a beautiful uniface lance-head of resolved or pecked work, kite-shaped, also a pebble worked into a fine pointed lance-head, thick-butted (it would appear not to be unfinished because many useful artefacts are found which still retain pebble-cortex on the butt), and free from all faceting, that is formed from a pebble or pebble-flake and not from a flake struck off a core with a prepared striking platform. Large triangular points numbered 20, retouched, 1; small points, 5; serrated or oakleaf points, 11, and two showing less decided serration; backed blades, 4; side-scrapers on parallel-sided flakes, broad and narrow, 6; serrated, 1; early scraper forms, 4; and a scraper with resolved flaking.

Site 10, the largest, is situated on the summit of the ridge, is some hundred of yards long, and of varying though considerable breadth in parts. In its centre part water-rounded pebbles, flakes, cores, and artefacts in their thousands abound, all deposited there by man. The outstanding archaeological features of the site are the small number of small hand-axes often much weathered and some even eroded by sand-blast, the high proportion of fresh-looking backed blades and large flakes with well-faceted butts. Many small and medium sized tortoise-cores from which convergent-sided flaked points with faceted butts were produced, and a few cores of cone-type from which parallel-sided blades have been struck off; and a large number of the Geelhout type points or arrowheads varying from 6 × 3 cm. to 12 × 6 cm.; one weathered upper millstone; large lancehead points, the whole surface of which is worked by resolved flaking, 2. Throughout the enormous assemblage on this site there is practically no serrated work, or oakleaves, while only one point with concave butt was found.

Of cores, the larger on this site are trimmed on the upper or striking platform with many parallel negative facets, the outer or cortex surface

is trimmed slightly or battered, and the points are removed from the working surface in single flakes from small core, or in series from the larger. Cores were commenced large for large points and ended as small cores for small points, and even then were used to produce points or sharp flakes by blows around the periphery, so producing a uniface disc.

For hammers water-worn boulders of convenient size were used, and in time, with battering, took on a pseudo hand-axe form.

Site 11 is on ground which slopes to the westward, and includes a standing pillar in the eroded area which gave certain important stratigraphical information (text-fig. 10). The top stratum is one foot of brown sand, with small hand-axes and Middle Stone Age material (G) *in situ*. Beneath it was hard-pan, followed by yellow sand one foot in depth (E), and red sand or loess one foot in depth to the base of the pillar, where a large almond shape Type III hand-axe or lance head was found *in situ*.

Site 12 is to the southward of 11. Here, above the layer of hard-pan, occurred small pebble-technique hand-axes, small hand-axes, a serrated long flake, a few long flakes or points and a small cleaver.

Site 13 is a white aeolian sand area, where Middle Stone Age material is found on and in this latest sand in circumstances which preclude derivation from a higher level. It produced serrated blades with faceted butts, medium-sized plain points, a few backed blades, and a few more highly weathered hand-axes of small size. Within this area were found the majority of the points with concave butt.

Site 14.—Here there is a stratum of 2 feet of brown sand superposed on an ancient eroded surface of mottled red loess. On the surface of the former was found one point of red jasper of Howieson's Poort type. On, and partly sunk in the lower red loess, were small hand-axes.

Site 15 was not extensive. It produced a perfect miniature cleaver 7·6 × 5·1 cm. (text-fig. 3, 2), associated with serrated points and backed blades.

Site 16 produced pebble-technique hand-axes, 2; smaller types, 3, including one with a finely thinned point of Type III hand-axe; a pebble section cleaver and innumerable backed blades. The points included triangular 11·4 × 7·6 cm., 22, of which only two were trimmed; two weathered oakleaves; one fresh round butt trimmed both sides in shallow points reproducing in miniature Type III hand-axe.

Site 17.—The uneroded surface area towards the sea side, which produced a few pieces of typical Howieson's Poort material on aeolian sand.

Section V. The Technique exhibited by the Geelhout Artefacts and their Morphology.

The Stellenbosch technique is distinctive and occurs rarely on this site. The Fauresmith technique is equally distinctive. There is no evidence

towards filling the hiatus between these two, though both of them occur above the red loess. Many implements show more affinity with North African Tachengit than South African Fauresmith. The existence of two forms of finely worked hand-axe, pointed and rounded, suggests that there is here a transition from the hand-axe with which a swinging blow was delivered, to a fine and effective lance-head with which the hunter delivered a penetrating thrust. The special mode of butt-thinning employed also supports this theory, *i.e.* a radial application of the shallow flaking. The technique is similar to that employed on the North African site, Tachengit. These large lance-heads are thinner in proportion to their breadth than are many of the small implements possessing the true hand-axe appearance. The technique also appears in smaller uniface implements which, if found sporadically, would immediately be classified as of Middle Stone Age. Secondary percussion-flaking is also used to improve the edge.

Percussion-flaking of two other types, produced by lighter blows than in the technique described above, occurs in the artefacts of this area. One is performed by blows delivered at right angles to the flake surface, producing serration; the other by blows delivered tangentially, producing resolved flaking, which has a laminated stepped or shattered appearance over the negative facets of the artefacts which, when highly developed and possibly finished by pecking, produces a regular, almost smooth surface. The serration of "oakleaf points" is apparently the first stage in the production of resolved flaked points. It is used for two distinctive purposes—first, for rapid reduction of a flake area; and second, the production of a steep bevel or greater convexity of the flake—that is, the production of balance as well as of a strong edge. Several artefacts show serration accompanied by slight resolved flaking. This suggests very strongly that the "oakleaf point" is not a distinct type, but is a stage in technique.

The Kasouga technique was first described by Hewitt in artefacts found by him at the place of that name in the Eastern Province. Though the term was first applied to a distinctive artefact of bar-scraper form, this secondary working of flakes on their positive faces on one or both sides is in itself distinctive. According to Goodwin and Lowe (2, p. 130) it is uncommon, and usually to be associated with Middle Stone Age. It has been found by Hewitt (3), the writer and others in Wilton association. The Hardy collection of Still Bay and Wilton material contains four such flakes, although it has been stated that it is unknown in the Cape Still Bay assemblage. It occurs in Howieson's Poort, and has been found in Middle Stone Age artefacts at Kowie, at Florisbad in the O.F.S., and with frequency on the Geelhout site where it is closely associated with serration. Kasouga and Wilton Kasouga trimming are both, however, on a more delicate scale than occurs here.

The shallow fluting on the large implements is certainly not pressure-flaking, but probably baton-flaking of the Tachengit type, and it appears to have persisted through a long period, and to have been applied to small implements at a later date.

There is on this site very little flaking which might suggest pressure, and this occurs on the butts of a few points, which have been thinned in a radial manner similar to that on the large highly finished hand-axe or lance-head.

The implements which, however, bridge the gap and form the link are points which the writer first classed as Levallois and in which the technique appears to partake both of Levallois and Tachengit characteristics, the faceting being prior to the detachment of the flake, but broad and shallow. These probably belong to an earlier phase than the resolved points.

When the Levallois tortoise-core is prepared, it has one or more slight ridges on its face surface representing the edge of previously removed parallel-sided flakes each of which may form the rib of a future point. The convergence of the two main lateral negative facets on a point is caused by a blow directed downward and slightly outward (as opposed to a vertical blow) when detaching the point, so that the line of fracture does not pass downward vertically, but from above, downwards and outwards, producing not a parallel-sided flake, but a triangular point. For the former the taller, more conical, core was used, for the latter the tortoise- or bloc-core. This appears to be the explanation of the occurrence of triangular flakes and long parallel-sided flakes on the same site.

Cores for side-blow flakes, of the Victoria West type, have not been found on the site, nor was any core of sufficient size to produce flakes for the larger cleavers, or the Type III lance head. The majority of the cores found on the site are water-worn boulders, prepared for use by being broken in half or by the battering of a face or broken surface to flatten it, after which that crude platform was flaked to improve it. Most cores were used for the production of many flakes or points. The surviving bloc-, tortoise-, or disc-cores all show signs of considerable use, and suggest also habitation of the site during a period in which cores decreased in size and smaller points were produced. Every core does not appear to have become a disc. In many cores the striking away of flakes around the periphery produced a disc, uniface or biface. (Disc cores became at times too conical for easy use, and the projecting side was struck off, giving a waste flake with radial negative facets.) When a disc is large and only shallowly flaked around its periphery, it must be distinguished from an ovate hand-axe.

The disc of the Kareedouw gravels is larger and shows no battering as would be produced by use as fabricator. Heese (3, p. 9) states that they occur in the Stellenbosch industry, sinuous-edged and flat-based, and

believes that they represent awls. No evidence to support this theory was found in this area. The similarity between Geelhout ovate hand-axes and the Kareedouw gravel discs in technique and appearance suggests their use as hand-axes and necessitates the use of qualifying terms when discussing discs of the various ages. The fabricator theory of the origin of the disc also finds, therefore, no support in the artefacts of this area.

Core implements of pebble technique, that is in which the whole pebble is transformed into an implement by removal of flakes, are common, mostly hand-points rather than hand-axes.

The varieties of discs found in this area are four:

A. The uniface disc, the commonest, which is the tortoise-core in its last recognisable stage, with one face of pebble-cortex, the other of negative facets. It is nearer square than discoid in shape and will, therefore, be called a bloc-core.

B. The more regular circular disc, still uniface, from which points or small short flakes have been removed from the periphery of the faceted surface by shallow flaking.

C. The first stage of a biface disc, the faceted face as in B, with additional flaking round the outer edge of the cortex face.

D. Finally the biface stage is reached in which both faces are faceted and no cortex remains. Types C and D are thicker than A and B. True biface discs are rare on the Geelhout site. Bifaces with a small central spot of cortex remaining occur.

Redirecting flakes show two surfaces with negative facets, one the removed portion of the prepared platform, the other the portion of the unduly overhung working face, and one positive surface, where it was separated from the parent block. No core of sufficient breadth or overhang was found from which such redirecting flake could be struck. The only true redirecting flake found was one small one in jasper, an unusual material for this site, and it occurred on the surface at an outlying portion of the general collection area, and was associated with material of Howieson's Poort type. This method of refreshing a core does not appear to have been in use during the main occupation of Geelhout.

Flakes produced for use at Geelhout include:

I. The side-blow flake from a large boulder core, the bulb of percussion being on the side of the projected implement; from such flakes the large cleavers were produced.

II. Parallel-sided flakes.

III. Triangular flakes for points of various descriptions.

IV. Pebble-section flakes in which there is cortex on or near the butt. These are used even for the finest implements and are a distinctive feature of the site and include knife-scrapers, hand-points, and a small cleaver.

V. Concavo-convex flakes 12·5 × 10·2 cm. occur, and many triangular flakes or points have butts that are concavo-convex. The reduction in size from the Stellenbosch hand-axe through the fine shallow-flaked lance-heads to the latest phase tiny implements of 5 cm. long is so gradual that it was possible to arrange a series with a variation of no more than 0·5 cm. between successive specimens. From the 15·3 cm. and 17·8 cm. lengths

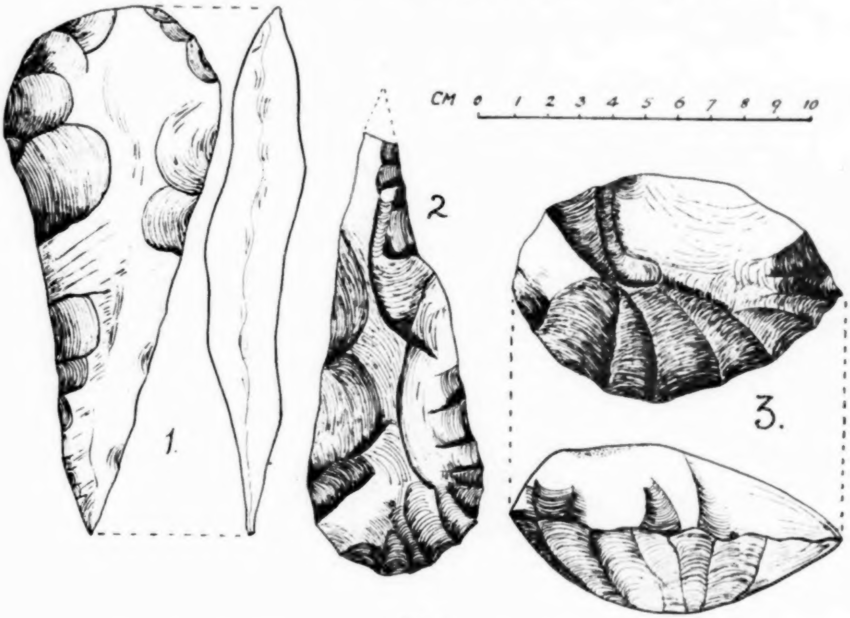

FIG. 5.
1. Slender pointed sinuous edged "hand axe", secondary working broad and shallow.
2. A similar implement, of better finish.
3. A "dumpy" hand-point of a type usual on this site. Core technique, cortex dotted.

there was a slight drop of 1·3 cm. to a series which varied from 14 cm. × 6·4 × 2·8 cm. to 8·8 × 5·2 × 2·6 cm. Pebble cortex is frequently present, and it appears that this was left so long as it did not interfere with the symmetry of the completed implement. The worker rejected hand-axes for a too-prominent bulge of the body, a wart-like excrescence difficult to remove on an otherwise flattish implement. An unusual type of pebble-technique, dumpy hand-axe of dimensions 10 × 7 × 5 cm. occurs, which is worked peripherally in shallow flaking (text-fig. 5, 3).

The cleaver, a type common in South Africa, has only recently received recognition by European archaeologists.

A. The Geelhout cleavers are all of sizes smaller than occur in the Kareedouw gravels, with one exception (text-fig. 2, B) which is 22·8 cm. long by 15 cm. broad, and differs from the Kareedouw series by its finer technique.

B. The Geelhout cleavers otherwise vary from 16·5 × 10·6 × 4·3 cm. to 12·5 × 6·7 × 3·5 cm. The edge is formed by two converging faces and is unworked. They are carefully worked round sides and butt, leaving the sharp straight flake edge unworked. The larger cleavers are worked on side-blow flakes.

C. The semi-cleaver, of narrow blade, with sides converging from the butt, parallels the oval-ended hand-axe of Type III and is a tool produced for some special purpose. It occurs from 19·4 × 8·9 × 3·7 to 16·1 × 9·3 × 4 cm. Thereafter there is a sudden drop in size to D.

D. A small cleaver of typical technique, found on site 15, 7·2 × 4·3 × 2·2 cm. (text-fig. 3, 2).

E. A series of rectangular flakes with a faceted butt opposing a sharp edge, 14 × 6 cm., which are sometimes pebble-section flakes thinned on the positive surface and with two trimmed sides, form the end of the series (text-fig. 3, 3 and 4) and shade off into the small F.

F. *Tranchet* scraper of the Middle Stone Age, certain of which possess slight secondary working. They are 9 × 5·5 cm. to 7 × 7 cm.

The lance-heads found here are the most beautiful productions of ancient man discovered in South Africa. They vary in size:

A. From 25 × 11 × 4·1 cm. to 7·5 × 4·5 × 1·8 cm. and have already been described in Section II.

B. The Tachengit Levallois, large broad points (not illustrated) are too large for arrows, and probably represent smaller lance-heads.

C. The large uniface resolved point found on Site 9 is too large for an arrow point and is undoubtedly a lance-head. It is the lance-head representative of the resolved phase, which is later than A. The larger, Pietersburg type, high-back points are also probably lance-heads. The two broken, but finely resolved flaked points, in which working was continued to produce an almost smooth surface, are a type not previously described.

D. The larger, specialised Geelhout type points are also probably lance-heads.

The hand-points—there is a definite series of implements which are not lance-heads or hand-axes, in which the butt is rounded and frequently retaining cortex. It appears to be a direct evolution from the hand-axe. Hand-points are of pebble technique (that is, core implements), being worked from the apex, and have finely spaced shallow secondary trimming of great regularity. The point is at times thinned to blade-like proportions. Hand-points also occur on flakes.

Others occur of smaller size, also on flakes, with thick butts, thinned blade-like point, only one of which possesses a faceted butt. There is great

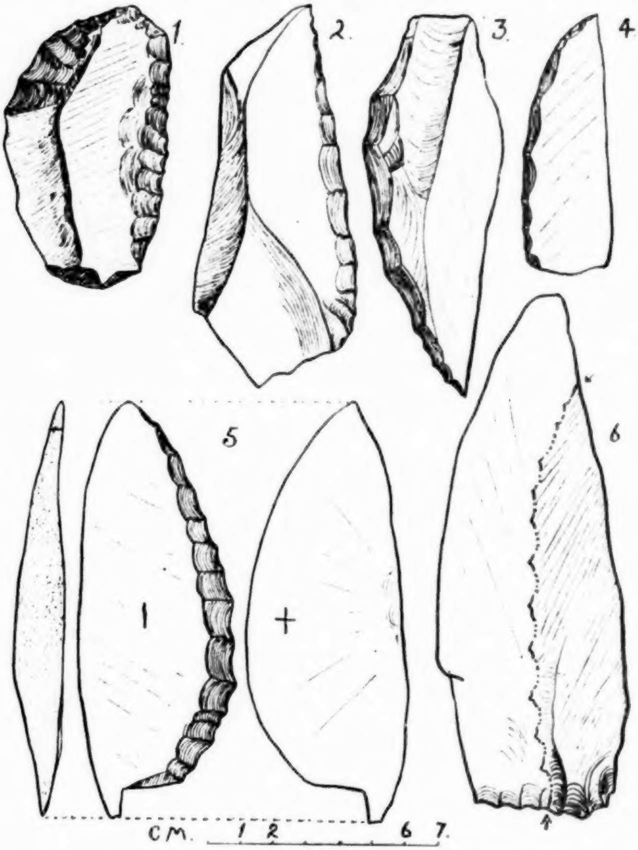

FIG. 6.—Backed blades.

1. Of scraper type.
2. Straight-sided scraper or part worked backed blade.
3. A true backed blade, back alone worked, showing flake origin, faceted butt.
4. Small backed blade, worked down to one facet of the original flake.
5. Three aspects of a large backed blade worked on a shallow broad flake.
6. Flake with faceted butt, showing diagrammatically the method of manufacturing a backed blade.

similarity between the blade-type hand-point and that of the smaller of the large lance-head types.

In practically all backed blades the bulb of percussion is partly worked

away at right angles to the plane of the flake, so producing the fluted back. Several show remains of the negative facets of the original flake-face. A few have trimmed edges. Text-fig. 6, No. 6, shows diagrammatically the mode of production of a backed blade from a long flake, the vertical trimming being done along the dotted line. The back of the blade is usually broad and convex, the sharp edge more or less straight. If the trimming of the back was finished more acutely at the butt end, the result would be a crescent. There is, however, nowhere on this area an indication of such a climax. They vary in size from 8 cm. to 15 cm. in length (text-fig. 6).

Knife blades (or side-scrapers) in which the cutting edge is worked occur on large pebble-section flakes. They are rare, only six having been found.

Scrapers:

I. Large, broad and thick flakes 12·7 × 7·6 cm. down to 14 × 2·6 cm. with shallow, fluted secondary work. In several there is a tendency towards the notching produced in the thin edge of the flake by vertical percussion, which appears here to be the first stage in making a side-scraper, the second being the removal of the projections, the production of a steep bevel, which was then trimmed by resolved flaking.

II. Rod scrapers, which may be divided into:

A. Parallel-sided in resolved flaking.
B. Convex, a single side being worked in resolved flaking.
C. Convex, double sided, also resolved.

III. Circular, highback, resolved scrapers.

These three types all belong specifically to the resolved flaking phase.

IV. The flat, circular palette-like artefacts, 7·6 to 10 cm. in diameter formed by exfoliation of granitic rock, must have been brought from some distance. In spite of their close superficial resemblance to artefacts found in the Transkeian Later Stone Age, and the Orange Free State Smithfield (which latter were used for mixing paints, forming both grindstone and palette), these are not in our opinion intended for such use. They are suspected to be circular scrapers, possibly unfinished, and the occurrence of the fine, circular, resolved scraper, though this is much thicker, supports this view.

V. The end scrapers of Site 7 confirm the suspicion induced by that of Site 6, that undeniable end-scrapers of large size must be included in the assemblage of certain Middle Stone Age phases.

Examination of the points shows that there are eight separate types or classes, with two methods of thinning keels:

(A) By blows parallel with the flake face directed from the butt, and so stepping it.

(B) By thinning from the side, with blows at right angles to the flake-

face. These are uncommon, and cannot be compared with the shouldered points which occur on other sites.

Type I. Heavy butted, large triangular-section flakes, high-keeled, long and all with intentionally rounded butts. The Pietersburg type (not illustrated here).

Type II. Preparation of the negative face by flaking previous to detachment of flake-point, which may be a later development, not fulfilling the requirements for Levallois, because the flaking for keel-thinning is parallel to the flake-axis. Butt-trimming occurs and secondary flaking along both edges is present. The point is slender, shapely and serviceable. Several of the secondarily worked specimens in Types I and II show thinning of the butt by the removal of short, broad flakes from the keel, producing a stepped or shattered appearance. Three points show Kasouga trim.

Type III. Points in which the thinning or narrowing process has removed the bulb of percussion and in which the whole negative face is refined by resolved flaking or pecking, producing an implement as finished in appearance in its own class, as is either the Type III lance-head or the Still Bay pressure-flaked laurel leaf in theirs. The technique is that of the "Pietersburg variation" carried to the ultimate degree of perfection (text-fig. 7, 9).

Type IV. The distinctive Geelhout point (text-fig. 8, 1, 2, 3, and 4) was worked as a flake, the midrib of which was eccentric, and usually situated to the left of the central line. These points are usually made from thin flakes. The amount of edge treatment varies, but the butt is invariably trimmed round. In only one instance is the right side of the point worked in full. The size of such points is variable. One broken specimen appears to have been at least 20·4 cm. long (a lance-head?), the smaller are only 7·5 cm. long. The large specimen combines faceted butt with secondary working and thinning of the butt on the positive face, with a Levallois aspect of the negative face.

The Geelhout point technique produced also double-ended implements, and thin, lenticular implements almost of Still Bay appearance, but in which only one edge is worked. There are high-backed or keeled points of similar method of production, and there appears to be direct connection in workmanship with the flakes and points of Levalloisian facies. The only heavily weathered blade of 15·2 × 5·1 × 1·8 cm. is narrow, multi-negative faceted, almost parallel, and slightly worked at the point. The only darkly patinated point of 5·1 × 3·8 cm. is stepped.

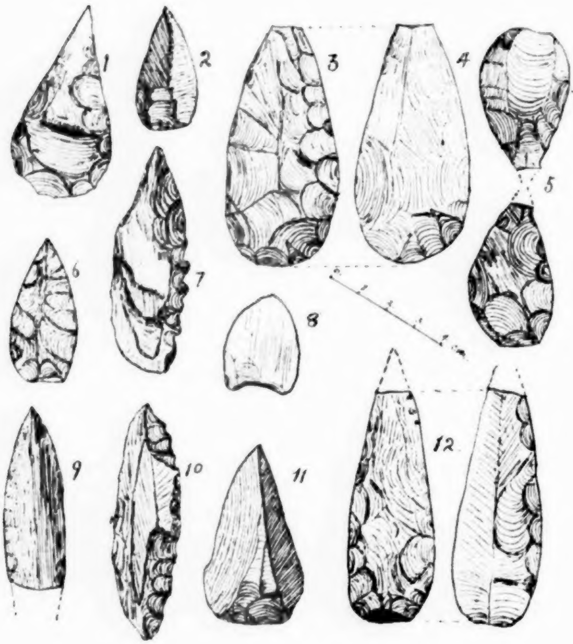

FIG. 7.—Points.

1. A thick butt, butt thinned and stepped, well-finished point.
2. A small point, faceted butt, thick and thinned to steps, small amount of butt-trimming on left side, otherwise maker considered original flake surfaces suitable.
3. A large point, negative surface, a questionable touch of Levallois technique.
4. Positive surface of same point, showing method of reducing thickness.
5. Small point, negative surface above, positive shown below. Thinning of butt particularly successful by a single blow.
6. Small well-finished point.
7. Large, serrated point, an unfinished example of No. 9.
8. A small point of type struck from bloc-core or disc, and needing little trimming, probably an arrow-head.
9. A broken, large, and beautifully finished lance-head, resolved flaking.
10. Another specimen similar to No. 7.
11. A flake point in which only butt-trimming was necessary to fit it for use.
12. A point, almost uniface, yet approaching Still Bay in appearance, but not pressure-flaked.

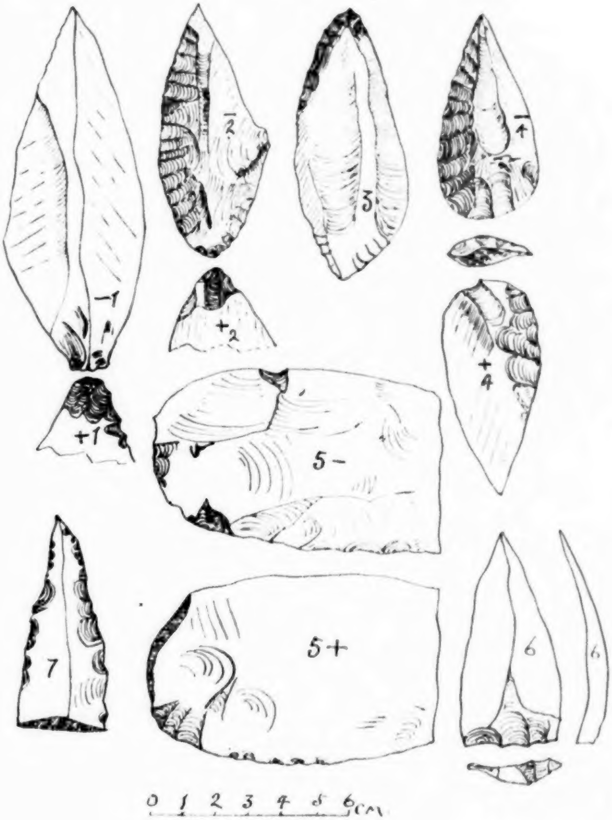

Fig. 8.

1. A large flake point of the type used in the production of Geelhout points.
2, 3, 4. Typical Geelhout points of Site 10.
5. Fragment of large point, probably a lance-head.
6. Curved flake, faceted, butt-thinned.
7. An irregular shaped point, an awl?

Type V. In the concave butt points (text-fig. 9, 2) there is usually little or no trimming of edges, the natural sharp flake-edge and point being used to the full. The butt is carefully prepared on both faces, producing a double-bevel thinning, and pseudo-barbing. Five only of these points show a little shallow fluting.

Types IV and V may merely indicate two methods of handling and working flakes of differing shape and varied usefulness within the same period.

Type VI. In a few points percussion flaking is combined with a shallow fluting which may have been produced by pressure. Two are worked over the negative faces only, and the keel is trimmed by percussion.

Type VII. Five specimens only show shallow fluting that may be pressure-flaking. Of these, three have butts trimmed and rounded by shallow fluting on both sides. One point has only its negative face trimmed at the edge.

Type VIII. One broken laurel leaf is of unusual material (text-fig 7, 12). It is worked over the negative face alone and is the only implement found within the area which might, without argument, be ascribed to Still Bay.

Seven points of fine resolved work from Sites 5, 7, and 8 and the general area were at first thought to represent awls. Each has lost its butt, and it is probable that they are merely broken arrow- or lance-points.

The Geelhout site has produced a wealth of method of butt treatment (text-fig. 9). The removal of a thick butt in the smaller hand-axes leaves a deep negative scar which appears also in many of the larger uniface points of Levallois facies. An arrangement of these implements on a long table showed a gentle gradation in form from the thicker implements with the deep negative facet thinning the butt; through long and slender 10·2 × 15·2 cm., to resolved uniface points, which also showed stepped butts, a method that is distinctive.

Prominent keels were thinned by striking off long flakes before detachment of the flake or point from the core, or after detachment by short broad flakes giving a stepped or shattered appearance. The amount of such trimming varies considerably, its aim was to produce symmetrical bevel and ease in hafting. These thick-butted, but otherwise well-finished, points and cores are probably earlier than the Geelhout and other, more easily hafted, points. Many of the points from Geelhout have convex or rounded butts, with facets that do not appear to be part of a prepared and rounded platform, and no core has been recovered on the site with a striking platform which is other than flat and at right angles to the long axis. This supports Heese's theory of the dressing of the flake for hafting (3, p. 15)—the Mousterian retouch. The material used here produces fine, sharp

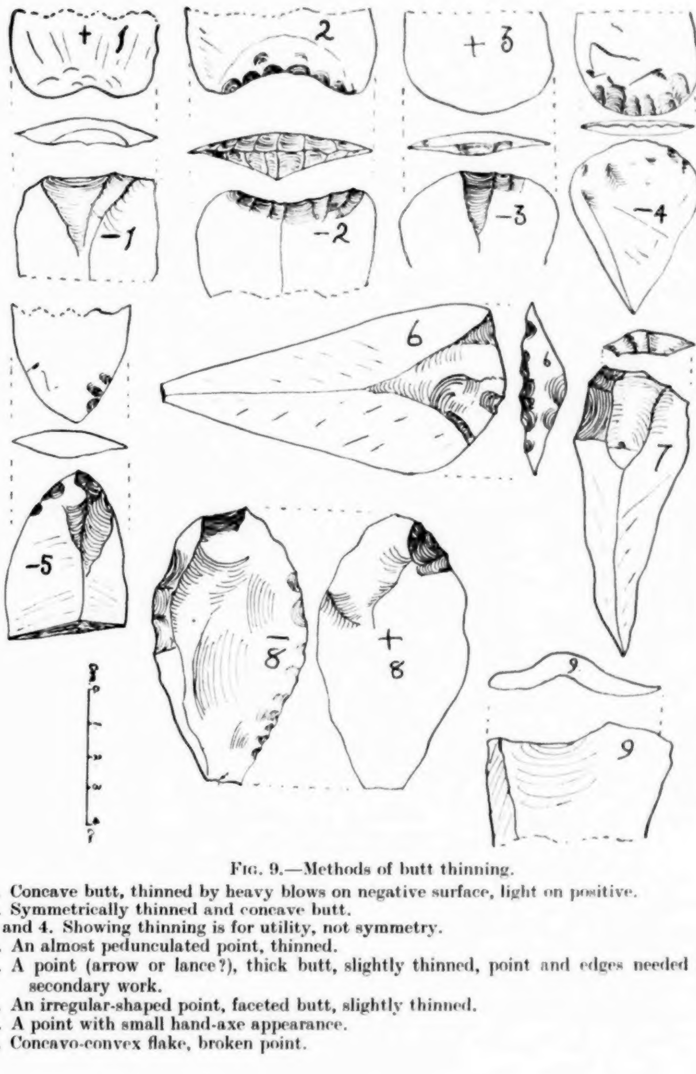

FIG. 9.—Methods of butt thinning.

1. Concave butt, thinned by heavy blows on negative surface, light on positive.
2. Symmetrically thinned and concave butt.
3 and 4. Showing thinning is for utility, not symmetry.
5. An almost pedunculated point, thinned.
6. A point (arrow or lance?), thick butt, slightly thinned, point and edges needed no secondary work.
7. An irregular-shaped point, faceted butt, slightly thinned.
8. A point with small hand-axe appearance.
9. Concavo-convex flake, broken point.

flakes, which needed only butt treatment to make hafting easy. This stage was followed by the slight working of the point shoulders, which when extended round the butt and one side produced the typical Geelhout point.

During the period represented at Geelhout, faceted and non-faceted butts occur side by side. The amount of faceting on any given butt naturally depends upon the size and number of the facets on the striking platform of the present core. The two types may, therefore, be synchronous. At its highest degree of excellence butt-thinning produced the concave-butt point, in which the rounded lateral barbs are secondary to the thinning process. In a few the base of a point was narrowed, and thinning of the base or butt resulted in oval or laurel leaf shape with no shoulder and no definite pedunculation.

The varieties of butt treatment may be listed thus:

A. Butts thinned by a blow leaving a deep negative facet, which occurs in small hand-axe type lance-heads, and large points.

B. A variety of A, thinning blow more nearly in the plane of the flake, producing a step. This occurs only in the hand-axe types of medium and small size.

C. The radially treated point-butts similar to the Type III hand-axe or large lance-head.

D. Convex butts, faceted, (1) as result of shape and preparation of core platform, (2) faceted by secondary work after striking of flake.

E. Convex butts, faceted and thinned.

F. A small series of points in which the butt is slightly pedunculated by removal of portion on either side of the bulb of percussion (text-fig. 9, 5).

G. Small rounded butts showing combination of percussion or resolved flaking with shallow fluting.

Section VI. Discussion.

The Kareedouw deposits (representing an early or first wet period) produced implements of Stellenbosch culture and above them, at the base of an upper stratum which is free from gravel, Middle Stone Age material which, unfortunately, is not ascribable to any particular phase. The separation between the two cultures is, however, stratigraphically clear. The Geelhout eroded area produced little true Stellenbosch material, and that which was found occurred in no archaeological or geological association except that it was above the hard red loess which in most areas signifies the end of Stellenbosch and the beginning of Fauresmith.

The stratigraphical evidence corroborates the conclusions suggested by differential distribution and weathering.

Not a single fragment of ostrich eggshell or pottery has been found, and so far no bone, while, except on the vlei side, which may be called Site 18—where six perforated digging-stones in various stages of manufacture were found—there was nothing to suggest an occupation of the

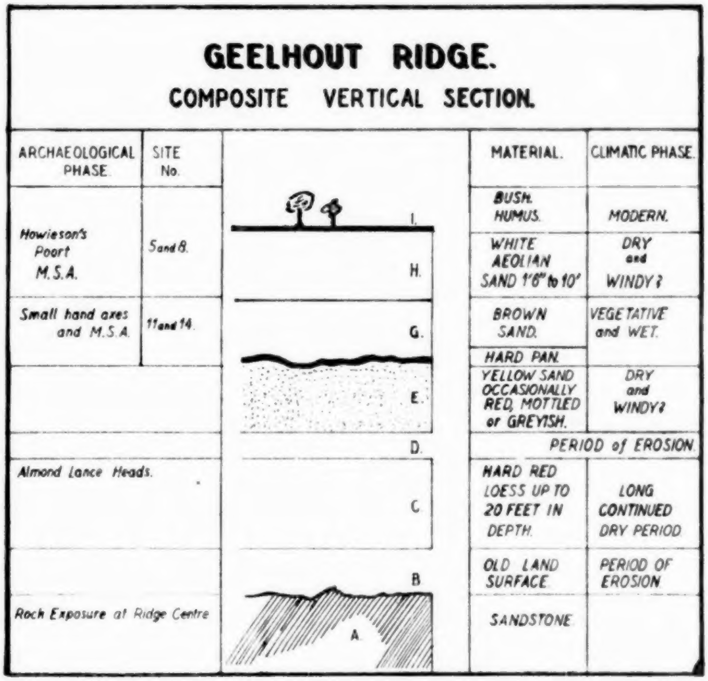

FIG. 10.—Geelhout Ridge. Composite vertical section of stratigraphy mentioned in text (second column) showing geological and archaeological detail, and probable climatic phases.

ridge during the Late Stone Age. It is important also to repeat that in spite of careful investigation not a single burin has so far been found and no core-scraper.

Most early and large forms were found embedded in the upper surface of the hard loess, probably an old eroded land surface (text-fig. 10). Over the whole area Middle Stone Age material when found above hard-pan was free from these earlier and larger types.

Arrangement of the Geelhout hand-axes by size and weathering produced less information than did a re-arrangement of sorting table contents

into classes of technique, which immediately suggested that as far as this area is concerned the flake hand-axe would be better allocated to the older series, and the large shallow-flaked "Tachengit" technique lance-head to a later series. The latter implements vary in length and shade down into lance-heads of Swaziland type, biface, 14 × 5·8 × 2·3 cm. The smaller flakes, uniface, of similar technique appear to be later. The stages from hand-axe to lance-head are clearly shown. In the earlier stages they possess Fauresmith characteristics without being typically Fauresmith. The smallest phase of this type of lance-head has a non-faceted butt with relics of the plain striking platform, or pebble surface, which is recorded also from Pringle Bay and the Transkei (P. W. L.) and, which I am informed, occurs at the Tugela Mouth in pure assemblage (van Riet Lowe).

In certain of the points of Levallois facies there is a distinct affinity with the larger and earlier lance-heads through the shallow broad negative facets and lack of extensive secondary working. They appear, therefore, to form a class intermediate between the earlier shallow-fluting and the later resolved technique.

The differential weathering on Sites 4, 11, and 13, and that of Site 6, suggests that the small thin hand-point is of later age than the small hand-axe. The weathering on Sites 4 and 6 suggests an earlier age for this industry and its distinctive large lance-head and a carrying-over of the technique of core preparation, with an addition of the Tachengit technique, and thereafter further development. This is corroborated by the occurrence of small hand-points with Middle Stone Age material on the late aeolian sand of Site 5. The assemblage of Site 10 and its differential weathering appear to separate the earlier Middle Stone Age hand-point phase from a later phase in which backed blades and the Geelhout points predominated, with the serrated and resolved phase as an intermediate.

Remembering that in Europe the hand-axe persisted into Mousterian times, care was taken to gather all evidence which might assist in proving or disproving the continued existence of the hand-axe into South African Middle Stone Age times. The problem was thereupon found to resolve itself into the question—"When is a hand-axe not a hand-axe?"

The term "hand-axe" can no longer be indiscriminately used for all artefacts which superficially resemble one another in shape or size. It certainly cannot be applied to the large shallow-flaked lance-head, or to the miniature hand-axe of five centimetres length, the use of which is as yet unknown. Is it possibly a form of awl?

The decline of the hand-axe, its replacement by the lance-head and hand-point, appears to have been less rapid on this site than in Europe, and the indications are that all these implements from the shallow-flaked lance-head onward have more affinity with the Middle Stone than with the Old Stone

Age. The gradual decline of the cleaver, through miniature forms, into the tranchet is demonstrated in detail by Geelhout material (text-fig. 3).

Goodwin in 1929 expressed the opinion that Fauresmith marked the culture transition from Stellenbosch to Middle Stone Age. Neville Jones claims Taungs material as typical of the oldest Middle Stone Age in South Africa, yet that assemblage contains undoubted burins. Burkitt (4, p. 138) states that attempts have often been made to derive the laurel leaf from an almond-shaped tool that has been refined and thinned, and to explain this distinctive object as an evolution of a type of Acheulean implement, which according to that writer certainly did not take place in central or western Europe, and still less in the various districts of the Mediterranean province which have been actually explored. The Geelhout material, however, suggests that in South Africa there is represented the evolution, direct from the South African Acheulean, of an industry which produced highly finished laurel-leaf shaped implements of a Middle Stone Age type.

The study of Site assemblages suggests that the large lance-head (hand-axe type III) belongs to an early phase of Middle Stone Age in which a broad shallow fluting technique of Tachengit type was practised (which is not a pressure process), which persisted through later phases until displaced by a tortoise-core flake technique phase in which serration and resolved flaking was practised, producing smaller though none-the-less efficient implements.

Many hundreds of specimens yielded only a small number of serrated thick broad flakes to which resolved flaking had been applied in order to work them down to narrow high-backs. Of aretfacts with serration, of all sizes, large numbers were found. This suggests a distinct phase in which appears a different technique in each of two stages of secondary working, the former representing workshop debris. The extraordinary fineness of the resolved work is no mere accident.

Serrated flakes with strongly faceted butts occur on Still Bay sites in the Cape and more commonly on the type site, and have in these circumstances been claimed as Still Bay. They occur also at Fish Hoek and Nordhoek (5). At these two sites large crescents of 8 cm. length down to 2·5 cm. are associated. The difference in technique and result between the oak-leaves and these crescents or pressure-flaked Still Bay aretfacts is as great as it could be, and such finds in small number on such sites probably represent an earlier use of the site rather than the products of a single industry. The Geelhout assemblages, however, suggest strongly that serration belongs to an earlier phase than Still Bay.

The serrated point ("Oakleaf") was a step in the production of resolved uniface points and these preceded the Geelhout points.

The assemblages of Sites 3, 7, 8, 9, 10, and 15 suggest a Middle Stone Age phase in which hand-axes of all types are absent, and in which percussion

was practised, and with resolved flaking as a tertiary or finishing process, in which parallel-sided flakes preponderate, and in which backed blades (which occurred on Sites 9, 10, 13a, 15, and 16) gradually became a feature.

If this theory is acceptable, it follows that the Glen Grey variation, of which resolved flaking is the characteristic, loses its minor place as a variation and becomes the poor representative of a definitely defined Middle Stone Age phase.

The Pietersburg high-back resolved flaked point is shown to belong to a special Middle Stone Age phase of resolved flaking, as do notched and barbed blades and Mossel Bay blades. It has been found on one site by the writer unmixed with any other form.

The existence of "Mossel Bay" as a separate variation is, therefore, seriously questioned.

Sites 8 and 9 show an advance towards the technique of Site 10, the largest and most prolific area, characterised by a late assemblage of fresh-looking artefacts including considerable numbers of Geelhout points, a large proportion of backed blades, and an absence of serrated work. The phase represented here is one in which all implements are smaller and finer in finish, and cores are smaller, in which the large lance-head does not appear, in which the arrow is in greater use, and in which the backed blade is common. We believe Site 10 represents the latest of the Geelhout phases of the Middle Stone Age.

No burin has been found on the Geelhout area, and Still Bay is not represented (except possibly by one broken uniface implement found alone), and pedunculation is undeveloped. The affinities of the industry of this area are with the Old Stone Age rather than with the Middle Stone Age.

The Howieson's Poort material, with the exception of two intrusive pieces, occurred on uneroded white aeolian sand of late origin—Site 17, representing the merest fraction of the finds, have nothing in common in material or technique with the artefacts or assemblages from other sites in this area. The point was submitted to Dr. Hewitt who corroborated the ascription. The crescents are typical. The former probably appeared on the site long after its desertion by the people of the Geelhout phases and after the aeolian deposition of white sand. That the Howieson's Poort phase is immigratory and synchronous with the late Middle Stone Age is shown by its intercalation between strata of Still Bay at Peers' Cave at Fish Hoek (6); at Mossel Bay it is found between occupations of Mossel Bay industry. At Durban North (P. W. L.) Howieson's Poort crescents are found on modern aeolian sand well above the storm beach level and associated with implements classed as Smithfield. The gap at Geelhout,

between the commonly represented phases and Howieson's Poort, and the absence of Still Bay, suggests that the Howieson's Poort phase is younger than the Geelhout phases.

The Bambata industry was expected to give the clue to the South African Middle Stone Age complex (7 and 8, p. 248). It was expected that earlier phases would be found in Rhodesia than in the Cape. The reverse now appears to be fact. In the Bambata series burins are abundant.

If the Bambata phase is the ancestor of the Cape Still Bay, its migration southward reached the Cape only after the full development at the Cape of a strong and distinctive Middle Stone Age industry directly from the Cape Acheulean, free from all pressure technique. The Geelhout industry appears to commence synchronously and collaterally with the appearance of Fauresmith at the close of a late Stellenbosch phase, because, though certain Fauresmith characteristics are represented, that industry's assemblage is not present.

Burins are plentiful in Howieson's Poort, and in Colonel Hardy's Cape Still Bay sites. The writer has found them in the Healdtown Fauresmith and in the late Middle Stone Age assemblage of a Transkeian cave. Careful search failed to disclose a single burin among the thousands of artefacts on the Geelhout area. Scrapers with faceted butts are common at Bambata, rare at Geelhout. The writer is left with the distinct impression that there are two strains of Fauresmith. One Fauresmith, well developed, includes burins; the other, that of the Geelhout phases, burin-free. This differential distribution of burins disposes of Bambata as a phase of origin of the South African Geelhout Middle Stone Age.

The high development of the Geelhout industry supports the theory that the Middle Stone Age developed within South Africa, slowly and through many phases, from the South African Acheulian, with a finely resolved flaking or pecking technique as its high-light. Then there was an accretion of migratory culture. There are certain similarities with European and North African material which are so striking that it would detract from the completeness of this description were they omitted. The cleavers found at Tachengit in North Africa illustrated by the Abbé Breuil (7) are paralleled by the large Geelhout specimens, as also are the *éclats Levallois retouchès*. This phase of Acheulian, developing into biface Middle Stone Age artefacts, is paralleled in Uganda, where the Upper Acheulian cleaver is also shown to develop into tranchet forms in the Tumbrian period (9).

The distinctive points at Geelhout are paralleled by the *Pointes lanceolées à encoches* of La Quina (10) in Central France. No claims of direct relationship are, however, made here. A comparison of Martin's Plate XVIII and our text-fig. 8, 2, shows the remarkable similarity between these highly specialised implements from sites so far apart. The presence of tranchet

scrapers (here the last phase of the cleaver) and the secondary working of alternate edges are also features of La Quina.

Section VII. Classification.

The following chronological classification is suggested for the phases represented on the sites considered in this paper:—

Old Stone Age.

I. Stellenbosch of the Kareedouw gravels. First wet phase.

II. Late Stellenbosch of Geelhout, above red sandy loess belonging to end of second wet phase. The "blow" phase.

III. Fauresmith represented, though its technique appears in the following phase.

Middle Stone Age.

IV. On an old land surface of eroded red sandy loess Tachengit shallow flaking was used to produce large beautifully finished lance-heads. The "thrust" phase. Large cleavers, butts usually trimmed radially, implements formed on large Proto-Levallois flakes of Victoria West type. (No cores found. Workshops on beach ?.) Specimens not wholly completed are found on site.

V. Butts radially thinned, Tachengit technique, associated with Levallois facies on large points.

VI. A period of luxuriant vegetation produced a brown sand stratum. Small hand-axes occur with Middle Stone Age material, tortoise cores with prepared platforms and small hand-points. Serration is used as a stage in the production of resolved high-backed uniface points, knife blades, circular high-back scrapers; Kasouga trim occurs.

VII. The Fauresmith contact or affinity with that of Tachengit has petered out, small hand-axes persist and cleavers in miniature form, developing into tranchet forms. Oakleaves common, points large and small in resolved flaking, arrow-points with concave butts, end-scrapers; serration and resolved flaking occur together. Resolved flaking produces its highest finished products. Kasouga trim a prominent feature. Concavo-convex flakes and end-scrapers occur.

VIII. The Geelhout point and backed-blade phase.

Late Stone Age.

IX. After a considerable lapse of time Howieson's Poort material is deposited by a visiting group.

X. And in recent times Late Stone Age man deposited a few digging-stones near the vlei.

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THE BEHAVIOUR OF THE F REGION OF THE IONOSPHERE OVER GRAHAMSTOWN DURING THE PARTIAL SOLAR ECLIPSE OF 14TH JANUARY 1945.

By J. A. GLEDHILL and M. E. SZENDREI.

(With two Text-figures.)

(Communicated by R. W. JAMES.)

(Read June 16, 1945.)

INTRODUCTION.

Since the Kennelly-Heaviside hypothesis of the existence of a partially conducting layer in the upper atmosphere was proved correct by Appleton, Breit, and Tuve and other workers, this region has come to be known as the Ionosphere. It was soon discovered to be compound in structure, and to consist of at least three sharply defined layers in the daytime. These are designated as the E, F_1, and F_2 layers, and occur, on the average, at heights of 100, 200 and 350 kilometres above the surface of the earth respectively. At night the F_1 and F_2 layers coalesce into a single region, now called the F region, at a height of about 250 kilometres. The E region is better understood than the others, partly because it was the first to be discovered and partly because it is the least subject to erratic variations.

It is generally agreed that these layers consist of ions and free electrons, and application of electromagnetic theory shows that the presence of these charged particles decreases the effective refractive index of the medium, the electrons being by far the most effective in doing so owing to their small mass. If the electron density is sufficiently high the refractive index may be reduced to zero, which is the condition for reflection of an incident electromagnetic wave. For a layer of given maximum electron density the effective refractive index decreases with decrease in frequency of the incident wave, and for a certain frequency—called the critical frequency—becomes zero; this means that the layer will reflect waves of all frequencies below the critical frequency but none above it.

Experimentally, the critical frequency may be determined by modulating a transmitter with pulses of short duration, and continuously increasing its frequency. A receiver is kept tuned to the transmitted frequency and its output is observed with a suitable monitoring device, *e.g.* a cathode-ray

oscillograph. This shows, in addition to the directly received pulse, a similar signal which has been reflected by one of the layers of the ionosphere. The frequency above which the reflection from that layer is no longer observed is the critical frequency for that layer, since complete penetration occurs for all higher frequencies.

Measurements on the ionosphere during solar eclipses have yielded enough information to establish fairly definitely that the sun's ultra-violet radiation is mainly responsible for the existence of the E region. In 1940 Higgs (1) was able to show that a very good correlation existed between the occurrence of flocculi on the sun's surface and the ionisation density of this region. Results for the F_1 region, although less definite, nevertheless indicate ultra-violet light as a source of energy for its production. In the F_2 region, however, large fluctuations often occur at almost any time of day; these tend to obscure any effects of an eclipse. Comparison of results obtained by several observing parties spaced along the path of totality has been used to show that there is very probably a true ultra-violet effect in the F_2 region also (1).

In view of this indefiniteness it is important that every opportunity of investigating the conditions of the ionosphere during an eclipse should be seized upon. Such an opportunity presented itself to the writers in the early morning of 14th January when a partial eclipse of the sun took place in Grahamstown, during which 0·88 of the sun's surface was covered.

Expected Effects of an Eclipse of the F Region.

During an eclipse of the sun, when part or all of the ionising agency is withdrawn, a decrease in the maximum ion density, N, of a layer will occur; this is due to disappearance of free electrons by recombination with positive ions or attachment to neutral molecules, etc. N is calculated from the critical frequency f_c, the two being related by the well-known equation:

$$N = 1{\cdot}24 \times 10^4 \,.\, f_c^2, \qquad . \quad . \quad . \quad . \quad . \quad \text{(i)}$$

where f_c is expressed in megacycles per second and refers to the ordinary ray. An eclipse is therefore expected to produce a dip in the curve of critical frequency vs. time. This dip will occur either simultaneously with or shortly after the optical eclipse in the ionosphere, if ultra-violet light is the ionising agency; but it will occur about two hours beforehand if neutral particles travelling at the limiting velocity of 1600 km. per sec. are responsible (2).

An eclipse occurring in the early morning offers little or no possibility of the successful fitting of a curve with any theoretical basis to the experimental result. At best the theory of the F region is very nebulous; even

for the E region, much better understood, the theoretical curves of Hulburt (3) and Chapman (4) do not fit very well the experimental values for this time of day. However, without making any assumption as to the processes of ion and electron production and recombination, it should be possible to express the rate of increase of ion density by an equation of the form:

$$\frac{dN}{dt} = q - \alpha N^2, \qquad \text{(ii)}$$

where q is the rate of ion production per cm.[3] and α is the effective recombination coefficient.

A fairly simple theory (5) shows that q is directly proportional to the cosine of the sun's zenith distance when this is less than about 70°, *i.e.* for the middle part of the day. Hulburt has developed a more accurate expression (3) which takes account of the earth's curvature and is applicable at any time of the day. Attempts to apply this expression to our experimental results gave no better agreement than that obtained by Hulburt in his application to the E region. Nevertheless equation (ii) may be applied, if q is allowed to vary with time in a suitable manner; reasonable physical considerations would demand that it should be a continuous function of time.

The recombination coefficient α is generally assumed constant. It is doubtful if such an assumption is justified in ionospheric problems, particularly in dealing with the F region. The value of α depends on the chemical composition of the part of the atmosphere concerned (6); since the heights of the F regions vary considerably between their day-time and night-time values, it is likely that the compositions of those parts of the atmosphere where the layers are situated vary with the time of day and α will therefore be expected to vary as well.

An expected curve for an ultra-violet eclipse of the F region may be drawn if it is assumed that the radiation responsible for the formation of that region comes uniformly from the sun's disc. If f is the fraction thereof not covered by the moon at time t, then equation (ii) takes the form:

$$\frac{dN}{dt} = fq - \alpha N^2. \qquad \text{(iii)}$$

Observation and Discussion.

The work reported in this paper was carried out using apparatus which was still in course of construction. The pulse transmitter covered the range 1·8 to 14 Mc./sec. and delivered an average output power of 60 watts during pulses. Its frequency was varied manually by the observer, who also tuned in the reflection on a superheterodyne receiver with the aid of a cathode-ray oscillograph and loudspeaker. Critical frequencies could be

read off to the nearest 0·01 Mc. and were in terms of a standard 100 kc. oscillator which was checked at regular intervals against the American Bureau of Standards station WWV. In spite of the small power radiated, complete penetration of the layers was observed in nearly every case; in cases where, on account of heavy static or absorption, complete penetration could not be followed, no critical frequency was recorded, unless the separation of the ground pulse and echo on the cathode-ray oscillograph screen corresponded to a virtual height of at least 1000 km.

Unfortunately the state of the apparatus was such that layer heights could not be determined with any accuracy or speed; however, a number of measurements taken directly on the screen of the oscillograph a few minutes before the eclipse agreed in giving a true height (obtained by the method of Booker and Seaton (7)) of the F region at that time as 250 km.; the times of eclipse were therefore calculated for that height.

(a) *Control Days.*

Control data were obtained at 10-minute intervals during the period 4^h to 9^h and at half-hour intervals throughout the rest of the day, for 4 days on either side of the eclipse day, and they showed the typical variations exhibited by the F regions from day to day and from hour to hour. In one respect, however, the graphs showed a remarkable regularity; no matter what the actual value to which the critical frequency may have fallen or risen during the night, it commenced to rise sharply to the daytime values almost exactly 45 minutes before ground sunrise.

It was thought wise to compare these data with magnetic variations on the corresponding days, in order to eliminate from the mean any highly disturbed days, and also to make sure that the eclipse morning was not attended by high magnetic activity. The nearest magnetic observatory to Grahamstown is situated at Hermanus, approximately 450 miles away. Professor Ogg kindly supplied us with three-hour range indices and magnetic-character figures for the days in question.* For purposes of comparison, maximum deviations of critical frequencies from the mean for all days, taken over three-hour periods, were correlated with the three-hour range indices; the correlation coefficients turned out to be much higher than was expected, never falling below 0·7 and in one case reaching 0·98. On the strength of this good agreement the critical frequencies for the 15th were omitted in taking the mean, as this was the only day with magnetic character figure 2. It was also gratifying to note that the magnetic character figure for the 14th, the day of the eclipse, was zero.

The mean curve of critical frequency for the ordinary ray, excluding

* The three-hour range index is defined and discussed by Bartels, Heck and Johnston, Terr. Mag. Atmos. Elect., xliv, 411 (1939).

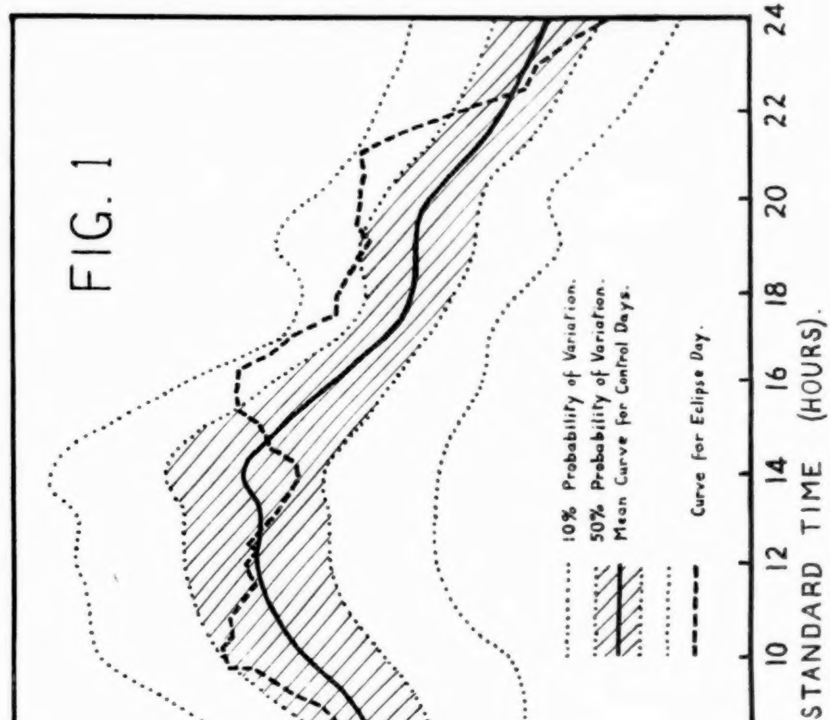


FIG. 1
ECLIPSE
at 250 km.
BEGINS MAX. ENDS
GROUND SUNRISE
10% Probability of Variation.
50% Probability of Variation.
Mean Curve for Control Days.
Curve for Eclipse Day.
CRITICAL FREQUENCY (Mc/s)
S. A. STANDARD TIME (HOURS).
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
14
16
18
20
22
24

data for the 14th and 15th, is shown in fig. 1. As an indication of the reliability of this curve as a standard of behaviour on any particular day, values of the "mean probable error" and of a frequency deviation with a probability of occurrence of 10 per cent. were calculated at hourly intervals: these are also indicated in fig. 1. Although deviations of natural phenomena from a mean curve are not errors in the strict sense of the word, the fact that an arithmetical mean is usually taken tacitly assumes a Gaussian distribution of fluctuations around that mean. Comparison with the individual graphs for each day has indeed shown that it is most improbable that any values of critical frequencies will be found outside the 10 per cent. probability band.

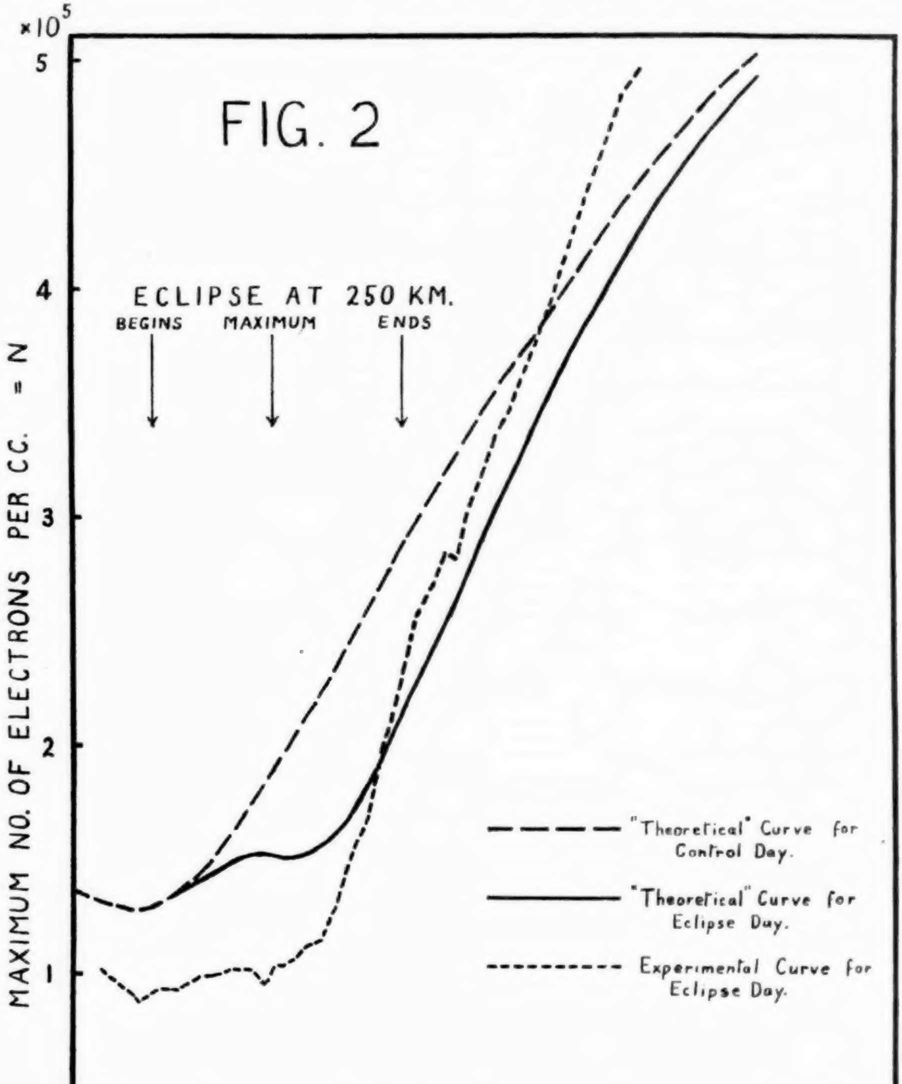
It has been general practice to conduct eclipse measurements at a place where the eclipse occurs during the middle part of the day, when it is assumed that the conditions will be steadier. Reference to fig. 1 immediately shows that wide fluctuations in the F_2 critical frequency may occur during this part of the day; this naturally makes it very difficult to label any dip that may occur as a definite effect of the eclipse. Indeed many investigators have been forced to admit that what seemed to be an eclipse effect in the F_2 region might just as well have been an everyday fluctuation (1), (8), and (9).

It was therefore with much satisfaction that we noted the very narrow width of the probability bands between 5^h and $6^h\ 30^m$, exactly at the time when the eclipse was due to occur over Grahamstown. It was therefore realised that any deviation from a curve of the normal type occurring over this part of the morning offered a better possibility of correlation with an eclipse than one occurring at any other time of the day. Radio measurements during an eclipse at this time of day have been reported by Naismith (10); it appears from his paper that no rapid increase of critical frequencies during the sunrise period was to be expected in England at the time of that eclipse; also a thunderstorm and a heavy magnetic storm were in progress at the time. Hence it is not surprising that Naismith could not draw a definite conclusion from his expériments.

(b) *Eclipse Day.*

On the morning of the eclipse, critical frequencies for the F regions were determined as frequently as possible, some 43 values being obtained between 4^h and 9^h. These are shown in fig. 1, and the corresponding values of N, the maximum electron density, calculated from equation (i), are shown in fig. 2.

It is at once evident from fig. 1 that the critical frequencies between $5^h\ 30^m$ and $6^h\ 20^m$ lie well outside the 10 per cent. probability area; a calculation for the value at $6^h\ 00^m$ showed that the probability of the



×10^5
5
4
3
2
1
FIG. 2
ECLIPSE AT 250 KM.
BEGINS
MAXIMUM
ENDS
MAXIMUM NO. OF ELECTRONS PER CC. = N
5
6
7
8
9
S.A. STANDARD TIME (HOURS).
"Theoretical" Curve for Control Day.
"Theoretical" Curve for Eclipse Day.
Experimental Curve for Eclipse Day.

occurrence of that value of f_c at that time on an ordinary day was less than 1 part in 10,000. While devoid of quantitative meaning, this at least serves to indicate that the curve of fig. 1 shows a definite eclipse effect.

Attempts to fit equation (ii) with both q and a variable to the mean curve by the solution of successive simultaneous equations yielded values of a which showed no definite trend, and which were as often negative as positive. It was therefore necessary to follow the lead of most other workers in the field and assume a constant. A value was calculated using the night-time condition $q=0$, which applies if it is assumed that the sun is the only source of ionising energy. Equation (ii) then becomes:

$$a = -\frac{1}{N^2} \cdot \frac{dN}{dt} \quad . \quad . \quad . \quad . \quad . \quad . \quad (iv)$$

Values of dN/dt and N were taken from the mean graph between the times of 0^h and $3^h\ 30^m$, during which period the fall was very even. This gave a mean value of a of $2 \cdot 8 \times 10^{-10}$. For the purposes of this investigation this value was assumed to apply until after the eclipse. Equation (ii) was then solved for q using values of dN/dt and N taken from the mean graph at 10-minute intervals and the values of q thus obtained were plotted as a function of time. The best possible curve was drawn through these points and the values of q taken from this graph were used in the calculation of the "theoretical" curves shown in fig. 2. (The graph for q is not shown here, but its form is strikingly similar to one which may be drawn from the values given by Appleton (11).) These theoretical curves were constructed by following the gradient stage by stage, using equation (ii) for the mean day and equation (iii) for the eclipse day.

Owing to the variability of the F region it would be an extremely unlikely event if the curve for any particular day coincided with the mean curve. At the time when the effects of the sun were first beginning to be felt, the critical frequency of the 14th January was approximately half a megacycle below the mean. The experimental curve therefore appears lower by a corresponding amount than the theoretical curve in fig. 2, although retaining the same general shape. The rather steep fall between $4^h\ 15^m$ and $4^h\ 30^m$ cannot be responsible for the deviations which we interpret as the eclipse effect for two reasons:

(1) the graph remains well within the 50 per cent. probability belt;

(2) the increase in critical frequency associated with sunrise is clearly visible, beginning at $4^h\ 30^m$, 4 minutes before the eclipse started at 250 km.

The fact that the experimental curve rises more steeply than the theoretical one appears to be associated with a sudden increase of the three-hour magnetic range index from 1 to 3 shortly after the eclipse. During the

preliminary comparison of these indices with the critical frequency variations it was noted that an increase in magnetic activity was nearly always accompanied by a significant rise in the critical frequency.

From this investigation the following conclusions may therefore be deduced:—

(*a*) A definite ultra-violet effect took place in the F region during this eclipse.

(*b*) Since the F_1 and F_2 regions were not differentiated at the time of the eclipse, the effect observed is in accordance with the theory of Berkner and Wells (12).

(*c*) The observed effect is in reasonable accord with the assumption that the ionising agency comes uniformly from the sun's disc.

ACKNOWLEDGMENTS.

It is a pleasure to thank Professor R. W. Varder for his constant encouragement and for making available to us the funds and facilities of this department during the research; also Professor A. Ogg of the Magnetic Observatory at Hermanus, Cape, for supplying the magnetic indices; and Mr. A. R. Morris, M.Sc., who came specially from East London to help with the continuous recording of critical frequencies for 10 days.

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PHYSICS DEPARTMENT,
RHODES UNIVERSITY COLLEGE,
GRAHAMSTOWN, SOUTH AFRICA.
16th April 1945.

A GROUND AXE FROM NATAL.

By C. van Riet Lowe, D.Sc.,
Director, Archaeological Survey of the Union of South Africa;
Professor of Archaeology, University of the Witwatersrand.

(With two Text-figures.)

(Read October 18, 1944.)

While on a visit to Natalspa, in the Pivaan River valley, near Paulpietersburg in Natal, during July 1944, Mr. G. J. Retief, the Mining Commissioner at Barkly West, examined two caves on the banks of the river. From the disturbed upper deposits of the floor of the cave immediately downstream of the hot springs he recovered a number of stone implements, some potsherds, and a few fragments of animal bones and teeth of living species of large and small antelope.

With a single exception, the implements represent well-known types that belong to the Natal variation of the Smithfield Culture with its preponderance of Y-shaped and strangulated notched scrapers, etc., that betray the Smithfield "N" division of the main culture complex (Goodwin, 1931; van Riet Lowe, 1936). The exception is the flaked and ground Neolithic-type axe illustrated in text-fig. 1. The ground portions are shown finely stippled. It measures 86 by 39 by 17 mm. in length, breadth, and thickness respectively, and, as it is the first occurrence of its kind from Natal, it demands a special note.* Three of the tools found with it are illustrated in text-fig. 2. The coarsely stippled areas represent natural surfaces. These are of indurated shale; others are of quartz and some of indurated shale with quartz veins.

The ground axe is made of an exceedingly tough, fine-grained amphibolite composed predominantly of an interlocking feltwork of minute hornblende needles. Professor T. W. Gevers, Head of the Department of Geology at the University of the Witwatersrand, kindly identified the rock for me and added that it is not uncommon in the Swaziland System which outcrops in the area. The indurated shale also occurs locally.

The fragment of rock selected was first of all roughly flaked into shape and then almost wholly ground over one face and partially over the other

* I am informed that Mrs. Gordon Bolitho has a ground axe from Weenen in Natal in a similar association, but as I have not seen it and as it has not been described, I am unfortunately unable to pass any comment or opinion.

until a good cutting edge was obtained at one end. In form it bears a very close resemblance to a ground axe from Rhodesia described and illustrated by Goodwin (1930: Cut 1, fig. 1).

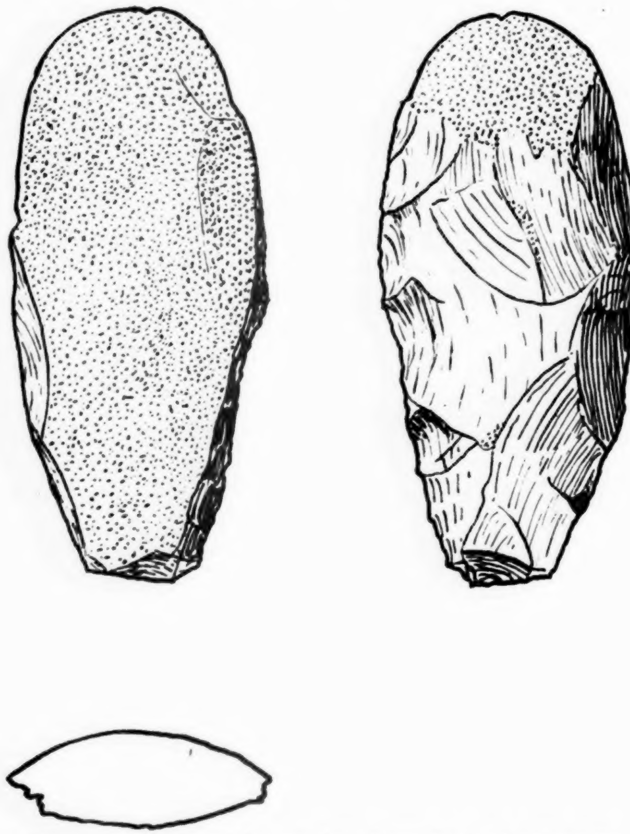

FIG. 1.—Showing top and bottom views of ground axe and cross-section. Natural size.

Its occurrence with Smithfield "N" tools does not surprise me in the least, for assemblages from living floors where tools of this culture were made include coarse pottery, grindstones (top and bottom), bored stones with well-ground surfaces, grooved rubbing-stones for shaping and sharpening cylindrical ivory, and bone arrow-points, bone needles, etc., very slender stone palettes as well as a fragment of a delicately ground stone arm-ring

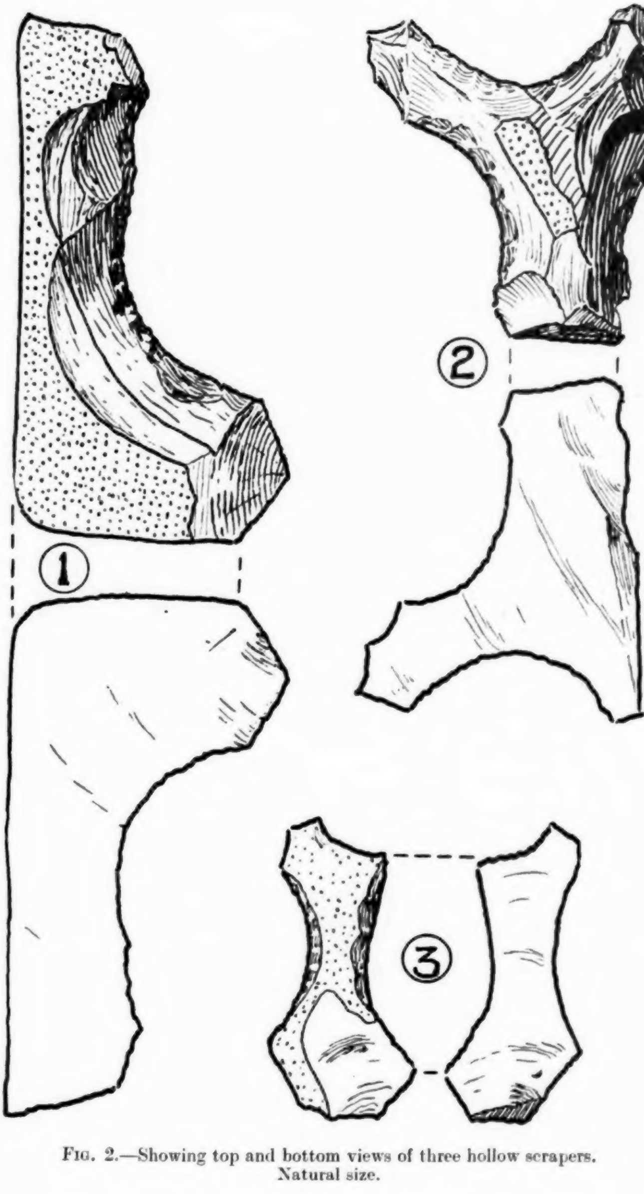

Fig. 2.—Showing top and bottom views of three hollow scrapers. Natural size.

recovered from excavations undertaken at Webster's Farm after the publication of my description of this site in 1936 (see "References"). The art of grinding faces and edges of stone, ivory, and bone tools by an abrasive process was well developed in the final stages of the Later Stone Age in South Africa. Numbers of cases of stone tools with ground edges and faces have been recorded in both the Smithfield and Wilton Cultures, and of ground edges and faces of stone, ivory, and bone tools in the Wilton and coastal Kitchen-midden Cultures. But of the numerous stone tools from the Union which reveal purposeful grinding as a finishing technical process of manufacture, only three of the hitherto described specimens recall *orthodox Neolithic-type axes or celts*. The first is the specimen from Grahamstown, described and illustrated by Péringuey (1911). "It is not," says Péringuey, "of the orthodox shape of the European or other Neolithic; and Mr. (now Dr. A. L.) du Toit shows that the maker availed himself of the natural contour of the stone." Only the sides of the cutting edge are ground; the remainder of the stone is natural. It cannot therefore be said to do more than *recall* orthodox Neolithic axes. The second and third specimens are from Peddie and Piquetberg in the Cape of Good Hope. They have been described and illustrated by Goodwin (1930). Like its Grahamstown fellow, the Peddie specimen is a conveniently shaped natural stone; in fact an elongated water-worn pebble, with one end ground on both faces to form a cutting edge. There was no preliminary flaking or "blocking-out" although, Goodwin adds, "one face of the polished portion shows signs of having been pecked previous to grinding operations". The Piquetberg specimen is equally interesting in that it was also roughly pecked into shape before being ground in a manner which was precisely the same as that employed in the manufacture of bored stones of the Smithfield, Wilton, and Kitchen-midden Cultures. In other words, the stone was chosen for its shape and not first flaked into shape, but merely pecked where pecking was necessary to reduce bulk before grinding was commenced. This was a common practice among the makers of bored stones that belong to the final Later Stone Age Cultures. Although these specimens recall and even resemble Neolithic forms in broad outline, the techniques employed in their selection and manufacture distinguish them from corresponding forms found elsewhere. On the other hand, the specimen illustrated in text-fig. 1 is "Neolithic" from both typological and technological points of view. As a specimen from the Union of South Africa it is therefore unique.

All the other South African specimens which have ground edges, whether supposedly for chopping or for cutting, *i.e.* for use as axes, adzes, chisels or knives or for any other purpose, are unorthodox. We have unassociated cutting and rubbing tools with ground and polished edges from the Cape of Good Hope described by Heese (1926), ground and polished palettes and

other "Neolithic" elements associated with the Wilton Culture in various localities and described by Hewitt (1926); we have the unique perforated stone axe together with another specimen with ground edges from Potchefstroom described by Goodwin (1930); a specimen with a ground edge from a Cape coastal Kitchen-midden site described by Drennan (1930); ground and polished lance- or spear-heads associated by Cramb with the Smithfield Culture in Natal (1934); unassociated spear-heads or daggers, beautifully ground and polished over both faces, from the Western Transvaal, described by Orford (1934), and other widely scattered "Neolithic elements" described by Goodwin (1929), as well as implements with ground and polished edges recorded by myself in intimate association with Smithfield B assemblages in the Orange Free State (1929).

In recent years more ground spear-heads or daggers have been found in the Western Transvaal, a ground stone arrow-tip, slightly tanged, from Chubani, near Thaba 'Nchu, in the Orange Free State, and a ground stone point from Healdtown in the Cape. The ground stone spear-heads or daggers from the Western Transvaal are mirror-images of those described by Orford. In my opinion they were made by Bantu-speaking people or by men who attempted to reproduce spear-heads in stone after the invasion of Bantu-speaking people a few centuries ago and not by men wholly in the Stone Age. The ground and slightly tanged arrow-head from Chubani is from a widespread culture that has not yet been described, a culture which includes both final Smithfield and Wilton tools in great variety and abundance, as well as small bifaced tanged arrow-heads illustrated by me in 1937. The ground point from Healdtown is quite exceptional. He who ground the edges and faces of this tool selected a typical Middle Stone Age flake with well-prepared striking platform and convergent longitudinal flake-scars on the face opposite the main flake face, and either rubbed the faces and edges down to their present well-smoothed contours or used the point in such a way that this wear resulted—the extraordinary, possibly unique result being a "neolithic element" on a perfect Middle Stone Age point! These specimens are housed in the museum of the Archaeological Survey.

We therefore see that of the many recorded "neolithic elements" from the Union of South Africa, only the Natal specimen described and illustrated in this essay is a typical Neolithic-type axe or celt in the sense in which this descriptive term is generally used. It may be said that the use of the word "typical" is not justified in that the axe is not as finely "finished" as are the best European specimens, but this does not invalidate the assertion that in this axe we have a *form* which occurs commonly in the true European and North African Neolithic. If, on the other hand, this axe and Goodwin's Rhodesian specimen, which it so closely resembles, are ultimately found to be among the best produced by Stone Age man in South Africa, then we

must agree that they are transitional forms which we should expect to find in an evolving Neolithic Culture. The very widespread occurrences of implements with ground or polished edges and surfaces in both the Smithfield and Wilton Cultures, the final phases of which were probably practised contemporaneously by Bush peoples who inhabited the sub-continent into historic times, show quite clearly that while these essentially palaeolithic peoples had reached a stage of development which is not truly Neolithic in that they did not practise agriculture and had no domestic animals, they enjoyed a material culture which includes typical Neolithic elements, the most convincing of which is this axe from Natal. Excluding the purely European Neolithic axes found at Knysna and described by me last year (1944), this axe is the only recorded one of its kind from the Union. When I think of the widespread remains of the Neolithic Age north of the Limpopo and of the Bushman in relation to the eland, and the accumulating evidence of the possibility of the occasional domestication of this animal by him, this axe and the other "neolithic elements" that occur south of the Limpopo suggest the emergence of man in the Union from the Palaeolithic to the Neolithic Age during the final phases of his occupation of this southern extremity of the continent. In other words, he appears to have stood on the brink of big and far-reaching developments. The widespread tendency to compare his material culture with the Palaeolithic of Europe is not therefore warranted by the facts before us. From what we know, we cannot say that his material culture was Neolithic, but the evolutionary plane he had reached when Hottentot and Bantu-speaking peoples and later Europeans invaded his hunting-grounds undoubtedly reveals him in an Epi-palaeolithic, if not in a Proto-neolithic, phase of development. He was not so advanced, nor was he so skilful as were his "neolithic" cousins of East and Central Africa, where a variety of true Neolithic axes occur in comparative abundance (Leakey, 1936); nor did he enjoy such a material culture as we commonly associate with the Neolithic of North Africa and Europe, but the facts before us clearly suggest a most significant metamorphism.

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THE ESSENTIAL OIL OF *AGATHOSMA GNIDIOIDES* SCHLECHTER.

By J. L. B. SMITH and D. G. ROUX.

(Read April 18, 1945.)

Among the lesser known plants of the family RUTACEAE of South Africa used as a herbal remedy is the species *Agathosma gnidioides* Schlechter. The genus *Agathosma* Willd. is endemic and confined to the extreme south of Africa, rarely if ever found inland north of 30° S., while the northern coastal limits are on the east the Bashee and on the west Namaqualand.

In the case of *A. gnidioides* there is some divergence of opinion among taxonomists as to its precise diagnosis, and hence some doubt about the distribution which may be accepted for that species. Fedde (Rep. Sp. Nov. Reg. Veg., 1913) regards the plant of the Albany district as a variety which he designates *glabrifolia* on the grounds that the leaves are entirely glabrous and not puberulous. Our observations indicate that this opinion should be accepted only with reservations, since we have been unable to find any sharply defined differentiation on those lines in specimens from a wide range of localities.

Agathosma gnidioides is a much branched woody shrub of 2–3 feet average height, attaining in favourable situations a height of 6 feet and an overall foliage width of 4–5 feet. It occurs only in the south-eastern Cape, having been recorded from Albany, Uitenhage, Port Elizabeth, Graaff Reinet, Fort Beaufort, and by us from Bedford. In the Albany district the plant grows chiefly in relatively good soil where moisture is fairly plentiful but not abundant. On any extensive predominantly arid slope or escarpment it may be found in sheltered clefts, on mist-bathed summits, and in colonies marginal to any copse of vigorous growth whose density and verdure show the presence of moisture. Such patches of bush differ markedly in their composition from the normal low thorny scrub in which they occur. Once the conditions favouring the growth of *A. gnidioides* are correlated one may from afar note with relative certainty where it will be found.

The foliage of this plant is most dense apically, the leaves almost encasing the twigs in the fashion of the Thymelaeaceous *Gnidia* Linn. after which it is named, while the leaves resemble in shape those of some species of *Gnidia*, being acuminate, rather small, on healthy plants 7–9 mm. in length and 1·7–2 mm. in width. On less robust plants they may be very much smaller though of the same shape. Oil glands are clearly visible in the leaf. Marginally somewhat exsert are on each side 7–13, while internally

there is a single irregular longitudinal row of 5–9 on each side of the midrib. In the Albany district it is possible to find both flowers and seed in any patch of the plant at any time as it flowers vicariously throughout the year, though most profusely and regularly in early spring. The small flowers are borne in apical clusters, almost umbelliform, the white petals each bearing 2–8 minute velvety purple spots in two parallel longitudinal rows near the apex.

As a herbal remedy *Agathosma gnidioides* is not extensively known outside the confines of its distribution, but has a great reputation as a stomachic, febrifuge, and antispasmodic among the farm natives of the Albany district. They are able to give precise directions to the rather restricted patches of this plant on named farms. Regarded as of great potency, an infusion prepared by boiling the leaves with water is employed. This is stated to induce profuse perspiration, to reduce fever, to relieve persistent cough, and to cause sleep. From our observations this infusion, although it can contain only a relatively low proportion of essential oil, is a nauseous concoction.

In an investigation of the oil of *Agathosma apiculata* Meyer, Smith and Rivett (Trans. Roy. Soc. S. Afr., 1946, p. 111) observed that the proportions of the components varied with the season. The same variation has been observed in the present case, and the actual oil content of the leaves has been found to vary also. The fresh leaves contained in February 0·61 per cent., in April 0·71 per cent., in May 0·77 per cent., and in July 1·0 per cent. of the oil.

Agathosma apiculata (Smith and Rivett, *loc. cit.*) was the first Rutaceous plant in whose oil a high proportion of sulphur was found, up to 13 per cent. of that element being present according to the season. The oil of *A. gnidioides* has now also been found to contain sulphur, but very much less, only an average of 2·4 per cent. being present. Analysis has shown that a low proportion of oxygen is present also in this oil, which is unique in containing up to 70 per cent. of terpenes.

Liberated by exhaustive distillation with steam from the fresh leafy twigs the dry oil had the following:—

	February.	April.	July.
d_{15}^{15}	0·833	0·836	0·837
N_D^{20}	1·4758	1·4796	1·4759
$[\alpha]_D^{20}$	−0·46°	−0·07°	−0·87°
Sulphur	2·35%	2·56%	2·51%

Elementary analysis showed the composition: in February 82·6 per cent. *C*, 11·4 per cent. *H*, 2·3 per cent. *S*, and 3·66 per cent. *O*, and in April 81·3 per cent. *C*, 11·0 per cent. *H*, 2·5 per cent. *S*, and 5·2 per cent. *O*.

Practically all of the oil distils over at 150–230° C. (725 mm.), with an obvious single maximum about 170°, and with little residue which is obviously chiefly polymerised products and which is greater the longer the oil is kept.

The oil has initially a pleasant aromatic odour which, as the more volatile portion evaporates rapidly, becomes pungent and nauseating. This rank odour clings tenaciously to clothing and person and is most unpleasantly enduring. From the skin, which the oil penetrates with ease, the odour may be removed only by drastic oxidation with permanganate or hypochlorite. These properties have rendered much of the investigation extremely unpleasant, all the more since degradation products of the higher fractions have proved to possess not only quite appalling odours, but so relatively high a toxicity as to cause in consequence periodic stoppage of work from the effects on the human system.

The oil is highly unsaturated and reduces permanganate instantaneously and extensively in the cold. Its components have been found to be:

1. Myrcene, about 60 per cent.
2. *l*-β-Pinene, about 5 per cent.
3. *l*-Limonene and Dipentene, together about 4 per cent.
4. *d*-Linalyl iso-Butyrate, about 25 per cent.
5. *bis*-(1-Pentenyl-2-) Tetrasulphide, $C_{10}H_{18}S_4$, a compound not previously reported in chemical literature, about 5 per cent.
6. A minute amount of free Butyric Acid, probably isobutyric acid, less than 0·1 per cent.
7. Most probably also, but in small amount, together less than 1 per cent. of the total, d-Linalool, Methyl salicylate, and Salicylic acid. Aromatic compounds otherwise appear to be absent.

It was not found possible to isolate the Linalyl iso-butyrate. Its presence has been deduced from products of hydrolysis and established by an extension of the quantitative elementary analytical method first employed by the senior author in the case of *A. apiculata* (Smith and Rivett, *loc. cit.*, p. 122). It has become obvious that essential oils of this type do not contain very many different compounds in any amount. The oil now described is shown to consist almost entirely of compounds $C_{10}H_{16}$, $C_{14}H_{24}O_2$, and $C_{10}H_{18}S_4$.

In further reference to the diagnosis of a species such as *gnidioides* it is possible that the nature of the essential oil may well prove a decisive factor in establishing whether plants from different localities are conspecific

or otherwise. Further it is suggested to taxonomists that in a family such as the RUTACEAE, where the essential oil is so marked a feature, the chemical nature of the oil may well provide a clue to a more fundamental generic differentiation. In that respect we suggest that the new sub-genus *Thiosma* be erected for those species of *Agathosma* Willd. which contain sulphides or polysulphides, and select *apiculata* Meyer as the genotype.

EXPERIMENTAL.

The separated leafy twigs were treated in 20-lb. lots with steam in a galvanised iron still 5 feet in height and 10 inches in diameter, packed as tightly and as full as possible. Separation of the oil from the distillate was facilitated by the addition of sodium chloride.

ELEMENTS.

Qualitative tests showed the presence of Sulphur. Quantitative analysis showed the presence of a relatively low amount of Oxygen also.

SAPONIFICATION VALUE AND IODINE VALUE.

As found previously by Smith and Rivett (*loc. cit.*), oils such as this which contain polysulphides do not yield constant values for the above under any conditions.

ACIDS: PHENOLS.

The oil showed a neutral reaction. The alkali extract of 50 gm. of the original oil when acidified yielded a very small amount of a liquid with strong acid reaction which possessed the pungent odour of Butyric acid, probably iso-Butyric acid (*vide infra*). This liquid gave with Ferric chloride a purple colour very like that produced with Salicylic acid. No indication of the presence of any phenols could be obtained.

UNSATURATION.

Halogens and halogen acids were rapidly absorbed by the oil. No crystalline products could be isolated in any case.

OXIDATION PRODUCTS.

Exhaustive oxidation by permanganate gave as chief products sulphuric acid, oxalic acid, and carbon dioxide. No higher crystalline acids could be isolated.

PHENOL ETHERS.

By Zeisel's method the original oil showed a very small amount of Methoxyl group. In view of the likely presence of Salicylic acid we suggest

that Methyl salicylate may account for this. Very considerable silver sulphide formed in the absorption flasks.

Reaction with Alkyl Iodide.

When the original oil was heated with methyl iodide in a sealed tube to 98° the mixture darkened rapidly with separation of oily matter and a few crystals. After 48 hours the partly resinous contents of the tube by extraction with water showed the presence of considerable ionic iodine.

Fraction V (p.338) containing 9·7 per cent. sulphur (4 gm.) was sealed in a tube with methyl iodide (8 gm.) and kept at 50° for three months. At the end of that time a considerable dark solid had separated. There was isolated from the contents of the tube more than 2 gm. Trimethyl sulphonium iodide in the form of yellow needles. Twice recrystallised from methanol the colourless product melted sharply at 203°. Found 62·2 per cent. *I*. C_3H_9SI requires 62·2 per cent. *I*.

This result shows that one-half of the sulphur in Fraction V had reacted with methyl iodide. This is what may be expected of the Tetrasulphide described later.

No indication that any other sulphonium iodide was produced could be obtained.

Aldehydes and Ketones.

From neither the original oil nor from any fraction could any evidence be obtained of the presence of aldehydes or of ketones in this oil.

Alcohols.

Owing to the presence of the polysulphide and to the reactivity of the higher fractions no definite evidence of the presence of any free alcohol could be obtained. What we observed here and in other reactions inclines us to the view that a very small amount of free Linalool may be present.

Distillation.

In a preliminary distillation of a portion of the oil at the ordinary pressure (725 mm.) it commenced to boil at 160° and showed a strong maximum at 175–179°. Thereafter the temperature rose steadily and almost regularly with no marked maximum. As some degree of decomposition as well as obvious polymerisation were evident during the later stages of the distillation, the main portion of the oil (900 gm.) was subjected to repeated fractionation *in vacuo* in a current of carbon dioxide. In this fashion were obtained at 13 mm. the following:—

TABLE I.

Fraction.	Temperature.	Per cent. Original Oil.	Per cent. Oil per °C.
I . . .	66– 70°	60·0	15·0
II . . .	70– 80	9·0	0·9
III . . .	80– 90	7·6	0·8
IV . . .	90– 95	4·7	0·9
V . . .	95–100	6·1	1·2
VI . . .	100–107	6·6	0·9
VII . . .	107–130	1·4	. .
Residue . .	. .	3·6	. .

From these the following information was obtained:—

TABLE II.

Fraction.	d^{15}_{15}.	N^{20}_{D}.	$[\alpha]^{20}_{D}$.	Per cent. C.	Per cent. H.	Per cent. S.	Per cent. O.
I . . .	0·819	1·476	−2·5°	87·7	11·8	0	. .
II . . .	0·826	1·483	+1·0	84·2	11·65	1·25	2·9
III . . .	0·867	1·483	+5·6	77·0	11·1	3·75	8·2
IV . . .	0·885	1·480	+8·25	73·6	10·8	5·3	10·3
V . . .	0·912	1·477	+7·23	69·6	10·2	9·7	10·5
VI . . .	0·933	1·486	+3·74	70·1	10·3	9·0	10·6
VII . . .	0·935	1·485	+3·53	70·5	10·2	9·4	9·9

The fall in rotation of Fractions VI and VII may be due to the presence of laevogyrate terpene (see Table IV).

FRACTION I: TERPENES.

MYRCENE. *l-β-Pinene. l-Limonene. Dipentene.*

It proved impossible to isolate from Fraction I by any process of distillation a sample of pure Myrcene. No product of density lower than 0·815 and optically inactive could be separated. To establish the presence of Myrcene some of this fraction (20 gm.) was added to Maleic anhydride (8 gm.) and warmed. A vigorous reaction set in which soon moderated. On cooling no solid separated. The product subjected to distillation *in vacuo* at 100° yielded unchanged terpene (10 gm.). The residue set on cooling to a mass of crystals which melted completely about 32°. The anhydride of 4-isohexenyl cis-tetrahydrophthalic acid melts at 34°. This

product was then heated on the water-bath with slight excess of aqueous potash and after cooling extracted several times with ether. The separated aqueous solution was evaporated when a potassium salt crystallised. This was dissolved in ice-water and treated dropwise with N HCl with stirring at 0° when a white solid separated. This recrystallised from a mixture of methanol and ethanol proved to be 4-isohexenyl cis-Δ^4-tetrahydrophthalic acid. Found 66·62 per cent. *C* and 7·90 per cent. *H*; also $E = 126{\cdot}5$, and melting-point 121°. $C_{14}H_{20}O_4$ requires 66·66 per cent. *C* and 7·93 per cent. *H*, and melts at 121°. It was thereby established that MYRCENE is present in the oil and from consideration of various data estimated at the extent of about 60 per cent.

The optical activity and density of Fraction I indicated the presence of other terpenes in Fraction I. By 12-hour refluxing of some of Fraction I with metallic sodium more than 50 per cent. was thereby rendered non-volatile by polymerisation. Twice repeated Myrcene still remained. The volatile remainder was treated with maleic anhydride and distilled. The distillate again heated with excess of maleic anhydride and distilled gave finally a product free from Myrcene which distilled over sodium at 719 mm. boiled at 156–172°, giving the following fractions:—

TABLE III.

Fraction.	Per cent.	Boiling-point.	d^{15}_{15}.	N^{20}_{D}.	$[\alpha]^{20}_{D}$.
T I . . .	20	157–159°	0·857	1·466	− 9·2°
T II . . .	52	159–161	0·853	1·469	− 12·0
T III . . .	18	161–165	0·850	1·469	− 17·8
T IV . . .	5	165–172	0·850	. .	. .

Each of the above fractions T I–IV proved to contain *l*-β-PINENE, since each by cold alkaline permanganate oxidation gave Nopinic acid as the main isolable product. Found $E = 184$ and melting-point 127°. Mixed melt with nopinic acid also 127°. From the density and rotation it was obvious that other terpenes were present also. Fraction T IV in particular had an odour exactly that of Limonene. The constants of the fractions pointed strongly to the presence of *l-Limonene*, but in view of the relatively low rotation of even T III it is very likely that *Dipentene* is present also. From not even T III, however, could we prepare any solid addition product characteristic of these terpenes. It has been shown by Conant and Carlson (J.A.C.S., 51, 3464, 1929) that Pinene and Dipentene cannot be separated by distillation. We prepared an artificial mixture of Pinene and Limonene.

This behaved almost exactly like T I–IV on distillation and we could not under any conditions obtain from it any solid addition product of Limonene. We have little doubt that Limonene and Dipentene are present in the original oil. The Pinene is estimated at about 5 per cent. and the Limonene and Dipentene together cannot exceed 4 per cent. of the original oil.

d-Linalyl iso-Butyrate.

Dextrogyrate Fraction VI (15 gm.) and KOH (15 gm.) in absolute ethanol were refluxed on a water-bath for two hours and the product steam distilled. The distillate was shaken with mercuric chloride solution to remove obvious mercaptans and again distilled with steam. The oily portion of the distillate was separated in ethereal solution and dried. This solution was treated with metallic sodium when a vigorous reaction occurred and solid matter separated, which was removed and washed free from terpenes. The solid was treated with water, extracted with ether, when the separated dried ethereal solution left on evaporation a pale yellow liquid (4 ml.) which was distilled *in vacuo*. The distillate at 715 mm. yielded 2 ml. of a colourless oil boiling at 192–193° of odour closely resembling that of Linalool. Found 78·3 per cent. C and 11·84 per cent. H: d^{15}_{15} 0·873, N^{20}_{D} 1·463. Linalool requires 77·93 per cent. C and 11·7 per cent. H: d^{15}_{15} 0·873, N^{20}_{D} 1·463. From its origin it was d-Linalool. We cannot from this state with certainty whether this was free in the oil or whether it originated by hydrolysis (but see later).

The residue in the original saponification flask (above) was treated with mercuric chloride to remove abundant mercaptides, the separated solids being removed by filtration. The clear filtrate was evaporated to dryness and the solid residue treated with a slight excess of 6N sulphuric acid. An oily acidic product separated which was extracted with ether, separated, and dried. Evaporation of the ether left a pungent dark liquid with the obvious odour of a butyric acid. On distillation this yielded the main fraction over 152–154° (716 mm.). Found $E = 88·5$. One drop failed to mix with an equal volume of water. Hence *iso*-Butyric *Acid*.

The oil is thus shown to contain an iso-Butyric Ester, most probably from the evidence Linalyl iso-Butyrate. Since the higher fractions are all dextrogyrate, and since it is later shown that the sulphide component is optically inactive and the terpene present laevogyrate, the ester must be dextrogyrate. We therefore deduce the presence of d-Linalyl iso-Butyrate.

All attempts to isolate this ester in a pure condition from the oil proved fruitless. Its presence is, however, strikingly confirmed by the quantitative evidence of Table IV (*vide infra*).

bis-(1-PENTENYL-2) TETRASULPHIDE.

All of the higher fractions reacted readily with metallic sodium. To 3 gm. sodium wire in absolute ether was added in small portions with shaking and cooling 20 gm. of Fraction VI. When the reaction had moderated it was completed by gentle refluxing for an hour. To the clear dark solution water was added drop by drop with shaking, when a light yellow solid separated. This was removed and well washed by maceration with ether. (This ethereal solution was retained—solution X—see p. 344.) The solid was dissolved in fifty times its volume of ice-water, the solution twice extracted with ether, and the separated aqueous solution filtered. To the clear filtrate cooled in ice was then added slowly with shaking a very slight excess of strong iodine solution. An oily compound separated which was extracted with ether. The ethereal solution was washed with very dilute thiosulphate solution, separated and dried. On evaporation of the ether there remained a light brown oil of most unpleasant odour. Found 45·1 per cent. *C*, 6·9 per cent. *H*, and 47·8 per cent. *S*. $C_5H_9S_2$ requires 45·1 per cent. *C*, 6·9 per cent. *H*, and 48·1 per cent. *S*. This unusual formula does not rest on a single analysis. Triplicate results in close agreement were obtained. This obviously indicates the Tetrasulphide $C_{10}H_{18}S_4$, which is confirmed by the fact that the compound is not volatile even at 180° under 3 mm. pressure. Also this compound explains the behaviour of the oil when heated with methyl iodide (*vide supra*), since tetrasulphides generally yield half their sulphur when brought to reaction in this fashion.

In order to investigate further the nature of this unusual compound, most of the fractions richer in sulphur were treated with sodium and finally with iodine as above. There was thus obtained 2·8 gm. of the light brown oil of unpleasant odour, the tetrasulphide. This had d_{15}^{15} 1·096 and showed no optical activity. During the preparation of the above material, one product deposited a small amount of crystalline sulphur on standing overnight, but this was not observed in other cases.

When it was attempted to fractionate this oil under 3 mm. pressure only a very small amount of material volatilised by 180° and the attempt was discontinued. In order to remove any free sulphur the main volume of the oil was treated with ten times its volume of cold methanol. All dissolved to a clear solution except 0·7 gm. of a heavy dark oil which when separated could not be induced to crystallise. This oil was found to contain 38·6 per cent. *C*, 6·7 per cent. *H*, and 54·7 per cent. *S*. It was thus likely a solution of sulphur in a polysulphide. Removal of the methanol from the above solution left a clear oil which was distilled for a lengthy period with steam. There resulted finally from the distillate 1·0 gm. of a pale yellow oil, while a similar amount of a darker oil remained non-volatile

in the flask. The more volatile portion contained 53·0 per cent. *C*, 8·1 per cent. *H*, and 39·9 per cent. *S*, and had d_{15}^{15} 1·040. The dark non-volatile oil contained 41·8 per cent. *C*, 6·4 per cent. *H*, and 51·1 per cent. *S*, and showed d_{15}^{15} 1·166. $C_{10}H_{18}S_3$ requires 51·3 per cent. *C*, 7·7 per cent. *H*, and 41·0 per cent. S, and $C_{10}H_{18}S_5$ requires 40·5 per cent. *C*, 6·0 per cent. *H*, and 53·5 per cent. *S*. These results indicate that the tetrasulphide on steam distillation tends to dismutation into trisulphide and pentasulphide.

Had the radicals in the original tetrasulphide in the oil not been of like size, in the resynthesis there would have been formed different polysulphides, one of them of lower molecular weight, higher sulphur content, and greater volatility than the others. This was not observed. It may therefore be accepted that this is a symmetrical tetrasulphide, *i.e.* a **Dipentenyl Tetrasulphide.**

To elucidate the full nature of this compound it was brought to reaction under ether vapour with metallic sodium, a reaction difficult to control. The sodium mercaptide so obtained, an extremely nauseous product, when freed from ether proved to be spontaneously inflammable in air. A great part of our product was lost in consequence, and only after several attempts was it found possible to bring the sodium mercaptide in absolute ethanolic solution to reaction with 2-4-dinitrochlorobenzene. No conclusive results were obtained, the sole isolable product being *bis*-(2-4-dinitrophenyl) sulphide.

A further amount (2 gm.) of the Tetrasulphide was prepared as above and boiled with water and potassium permanganate added 1 gm. at a time until oxidation was complete. During the oxidation, which took some hours to complete, at no time could the odour of acetone or of anything but the polysulphide be detected. Freed from precipitated manganese dioxide the solution was found to contain considerable sulphate. The solution was acidified with sulphuric acid and twice extracted with ether. The separated ethereal extracts were dried overnight, and on evaporation of the ether there remained a small residue which partly crystallised. This had the odour of an aliphatic acid, neither acetic nor butyric acid, very like propionic acid. The small mass was treated with 2 ml. benzene and gently warmed. The solid acid did not dissolve and was easily separated and identified as Oxalic acid, more being subsequently obtained from the above extracted oxidation solution evaporated to a small bulk. The benzene solution on careful evaporation left a small amount of liquid with the odour of propionic acid, which we were able to identify positively as that acid. The only other product of oxidation found present was carbon dioxide.

The evidence thus obtained, *i.e.* optical inactivity, almost certain symmetry of structure, and the production of oxalic and propionic acids on

oxidation together with the absence of acetone from the oxidation products, points strongly to the structure *bis*-(1-Pentenyl-2) Tetrasulphide:

$$(CH_3—CH_2—CH=CH—CH_2)_2S_4.$$

From the amount of sulphur present in the oil the amount of the tetrasulphide averages about 5 per cent. of the whole oil.

Composition of the various Fractions.

Fraction VII (p. 338) was found to contain 70·5 per cent. *C*, 10·2 per cent. *H*, 9·4 per cent. *S*, and 9·9 per cent. *O*. Assuming that the sulphur was present only as $C_{10}H_{18}S_4$ and the oxygen only as $C_{14}H_{24}O_2$, there would be 19·7 per cent. of the tetrasulphide and 69·3 per cent. of the ester in this fraction, leaving 11 per cent. to be accounted for. 19·7 per cent. of $C_{10}H_{18}S_4$ and 69·3 per cent. of $C_{14}H_{24}O_2$ together account for 60·9 per cent. *C*, 8·8 per cent. *H*, 9·9 per cent. *O*, and 9·4 per cent. *S*, leaving the unknown 11 per cent. as 9·6 per cent. *C* and 1·4 per cent. *H*, with neither oxygen nor sulphur. This points immediately to $C_{10}H_{16}$, which requires 9·6 per cent. *C* to 1·35 per cent. *H*, thus pointing to the presence of Terpenes and possibly of sesquiterpenes in Fraction VII. In consequence the ethereal solution X (p. 341) and similar solutions from the higher fractions were evaporated. The resulting oily matter was heated for 24 hours with excess of metallic sodium and finally distilled *in vacuo*. A small amount (5 ml.) of colourless distillate boiling at 60–75° (13 mm.) was obtained. Distilled over sodium it boiled at 163–178° (720 mm.) and from the odour contained both Myrcene and Limonene. As the object of this work was merely to establish the presence of terpene in the higher fractions the nature of the mixture obtained here was not further investigated, except that it was found to be feebly laevogyrate and of low density.

Whereas by accident a mixture of three different compounds may occasionally be of such a nature as to fit an analysis, it is scarcely possible for it to recur as shown in Table IV. In each case in that table the calculation is made on the assumption that the sulphur is present only as $C_{10}H_{18}S_4$ and the oxygen only as $C_{14}H_{24}O_2$. The resulting analyses in Table IV of the quantitative data show that there is very little doubt that this assumption is correct.

Non-Volatile Residue.

In each case the amount of non-volatile residue increased the longer the oil was kept. Freshly prepared oil left practically no residue when distilled immediately in absence of air. All residues proved to contain some sulphur.

TABLE IV.

Sample.	$C_{10}H_{18}S_4$.	$C_{14}H_{24}O_2$.	$C_{10}H_{16}$.	C.	H.	S.	O.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Whole oil, February.							
Found . .	..	..	..	82·6	11·4	2·3	3·7
Required by .	5	25	70	82·8	11·3	2·4	3·6
Whole oil, July.							
Found . .	..	..	..	81·3	11·0	2·5	5·2
Required by .	5·2	36·4	58·4	81·2	11·1	2·5	5·2
Fraction I.							
Found . .	..	..	..	87·8	11·8	..	..
Required by .	..	..	100	88·2	11·8	..	..
Fraction II.							
Found . .	..	..	..	84·2	11·6	1·25	2·9
Required by .	2·6	20·6	76·8	84·4	11·4	1·25	2·9
Fraction III.							
Found . .	..	..	..	77·0	11·1	3·75	8·2
Required by .	7·9	57·8	34·3	77·1	10·9	3·75	8·2
Fraction IV.							
Found . .	..	..	..	73·6	10·8	5·3	10·3
Required by .	11·2	71·4	17·4	73·9	10·5	5·3	10·2
Fraction V.							
Found . .	..	..	..	69·6	10·2	9·7	10·5
Required by .	20·2	74·2	5·6	69·8	9·9	9·7	10·6
Fraction VI.							
Found . .	..	..	..	70·1	10·3	9·0	10·6
Required by .	18·7	74·2	7·1	70·3	10·0	9·0	10·6
Fraction VIA.							
Found . .	..	..	..	71·2	10·4	7·8	10·6
Required by .	16·3	73·7	10·0	71·4	10·2	7·8	10·6
Fraction VII. . .							
Found . .	..	..	..	70·5	10·2	9·4	9·9
Required by .	19·7	69·3	11·0	70·7	10·1	9·5	9·9

CLINICAL PROPERTIES.

No opportunity has, as yet occurred for a properly controlled test of the clinical properties of this oil. The unpleasant effects of derivatives of the oil have deterred us from any personal test of the effect of infusions.

SUMMARY.

Agathosma gnidioides Schlechter, a Rutaceous shrub found only in the south-eastern Cape, has a high reputation as a herbal remedy among the natives of those parts. The fresh leaves contain in summer 0·6 per cent., in autumn 0·7 per cent., and in winter 1·0 per cent. of essential oil which has the following composition:—

1. Myrcene, about 60 per cent.
2. *l*-β-Pinene, about 5 per cent.
3. *l*-Limonene and Dipentene, together about 4 per cent.
4. *d*-Linalyl *iso*-Butyrate, about 25 per cent.
5. *bis*-(1-Pentenyl-2) Tetrasulphide, $C_{10}H_{18}S_4$, a compound not previously reported in chemical literature, about 5 per cent.
6. A minute amount of free Butyric Acid, probably iso-butyric acid.
7. Most probably also, not exceeding together 1 per cent. of the whole oil, small amounts of d-Linalool, Salicylic acid, and Methyl salicylate. Aromatic compounds appear otherwise to be absent.

The authors wish to express their gratitude to the National Research Board of South Africa for financial assistance which defrayed part of the costs of the investigation. Also to L. Jolly, Esq., on whose farm Upper Gletwyn of Albany all the material was obtained.

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March 1945.

TERRACES IN THE LOWER PART OF THE SUNDAYS RIVER VALLEY, CAPE PROVINCE.

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(With Map (Plate XI) and one Text-figure.)

(Read August 15, 1945.)

CONTENTS.

Introduction.

The Sundays River and its numerous headwater tributaries have their source in a rough semicircle of mountains, 100 miles in length, including, principally, the Sneeuwberg, 170 miles in a direct line from the sea and at a height of approximately 6000 feet above sea-level. Over its 250 miles of course its mean gradient is 24 feet per mile. The present investigation is concerned with the last 50 miles, from Courans Drift to the sea, where the mean gradient is 7 feet per mile. The last 13 miles, below Barkly Bridge, are tidal, the range of tides being approximately 5 feet during spring tides, near the mouth.

Below Courans Drift, but excluding the tidal reaches, the volume of water in the channel is normally quite small so that in some stretches it flows in a stream only a few feet wide, with moderate velocity, across the boulder-strewn bed of the flood-water channel; elsewhere it is ponded behind low rock-bars to form wider stretches of quiet water a few feet in depth. At such times of low water the river rarely exceeds 50 yards in width and is at most places much narrower. It can be forded at many

places. In contrast, during floods the water rises in the space of a few hours to 40 or more feet above its low-water level, submerging to a depth of 20 feet the low and narrow flood-plain, but in few places spreading laterally for more than 100 or 150 yards before being arrested against the confining scarp-faces of river-terraces. Below Mackay Bridge, in the tidal reaches, the channel increases in width in a downstream direction and, at Colchester, is occupied by a sheet of water about 120 yards across and 10 to 20 feet in depth. Here the flood-waters rise to about 12 feet above mean tide-level, submerging to a depth of only 5 feet the correspondingly low flood-plain. The height of both flood-waters and flood-plain diminishes steadily downstream until near the sea both attain only a foot or two above high tide-level. At the sea the estuary is almost closed by a sandy spit protruding northwards from the sand-dunes, which form the south bank, and the river finds its way to the sea through a comparatively narrow channel.

Hydrological data are available for the region above Lake Mentz (Lewis, A. D., 1935), some 75 miles from the sea along the course of the river, and since the greater part of the area of the catchment lies above this point the data afford some measure of the hydrological conditions in the reaches under consideration. A notable feature is the considerable variation in the annual discharge. For instance, at Lake Mentz, and up to September 1935, the mean annual flow was found to be 145,983 acre-feet, while the maximum recorded value was as high as 498,707 and the minimum as low as 17,481 acre-feet. The maximum discharge generally occurs in the period from December to April, as determined at Lake Mentz, with a maximum in January, of about 30 per cent. of the mean annual discharge, and a minimum in June equal to about 1 per cent. of the mean annual discharge. On the other hand the maximum discharge in any year is not necessarily confined to the period specified, for the considerable flood of 1944 occurred in May, while that of 1931 occurred in October. In fact, at the present time, the incidence of floods seems to be quite unpredictable in respect of both seasonal occurrence and frequency. The records of recent floods which the writer has so far been able to collect suggest that major floods occur at intervals of three to eight years.

Major Physiographic Features of the Region.

The geological features of this area are shown on Cape Sheet No. 9 of the Union Geological Survey (Haughton, S. H., 1928). This, and the map of Pl. XI, may be consulted for the location of places mentioned in this paper.

At Courans Drift the river leaves its gorge through the Palaeozoic Witte-

berg quartzites of the Klein Winterhoek mountains and for the rest of its course flows over the easily erodible rocks of the Cretaceous Uitenhage Series. The lower part of the valley is deeply trenched below the level of the base of the Tertiary Alexandria Formation. The latter forms a thin cover on the seaward-sloping, stepped plateau which borders the valley on the west, and, in contrast, attains considerable thickness in the undulating and higher Addo Heights, east of the river. The base of the Alexandria Formation is as high as 1000 feet above sea-level at its landward margin and descends to about 150 feet where it passes beneath the broad belt of coastal dunes, about 2 miles from the sea. Since the entrenchment of the river below the level of the Alexandria Formation, the scarp-edge of the western plateau has receded to a distance of 9 miles from the river, between Addo and Kirkwood, but to only about 3 miles from it near the sea. Between the scarp and the river lies a flight of terraces cut in Cretaceous rocks. Similar terraces are represented on the east side of the valley, above Addo, but with smaller areal development. The high terraces have suffered considerable dissection by the Coega-Kamma, Bezuidenhouts, Kudus, and Coerney rivers, the larger tributaries of the Sundays River, occurring at and above Addo Drift. The amount of dissection effected by these tributaries far exceeds that of the tributaries below Addo Drift, and it seems that they are much older streams. It is probable that dissection of the Alexandria Formation began very much earlier inland than near the sea, and that the initiation of erosion there dates back to at least the beginning of the retreat of the Tertiary sea. As the sea withdrew, the valley was extended seawards so that to-day the dissection of the higher terraces and the development of tributary streams is much less advanced in the lower reaches than in the higher. At least one of the higher terraces appears to be continuous with a step in the surface of the Alexandria-capped plateau, west of the river, bearing witness to a halt-stage in the retreat of the Tertiary sea. Such a relationship between river-terraces, fluviatile gravels, and Tertiary strand lines has been forecast elsewhere (Haughton, S. H., 1925, p. 32).

The present paper deals with only the lower and younger terraces, though the selection of these is not entirely arbitrary. The flight of terraces falls naturally into two groups, which, for convenience of description, are designated the *Higher Terraces* and the *Lower Terraces.* The Lower Terraces are graded to sea-levels below 100 feet; the Higher Terraces to sea-levels at and above 170 feet. The two sets of terraces are clearly demarcated in the field by a steep and prominent escarpment, varying from about 70 feet in height, near the sea, to as much as 200 feet near Sunlands. The Lower Terraces occupy that part of the valley mapped as alluvium on Geological Sheet No. 9, so that it is clear that Dr. Haughton

also regarded the Lower Terraces as in some way quite distinct from the Higher Terraces.

Method of Investigation.

The primary object of the field work has been to prepare a map of the terraces and to determine heights as frequently as possible on them with a view to constructing length-profiles. A Cape Divisional map on a scale of approximately ½ inch to one mile has proved adequate for the purpose. Heights were determined by theodolite or Abney Level, the former to determine the heights of "base-points", from beacons, and the latter to determine small differences of height between adjacent terraces. In the determination of heights from distant beacons distances were measured from the map. This was found sufficiently accurate to maintain a margin of error at less than 5 feet. The distances to near beacons, involving large angles of elevation, were measured by means of a range-finder of 30-inch base. Most of the spot heights refer to parts of the terraces which are sensibly level in transverse profile, and due consideration has been given to local departures from this condition.

An important aspect of the field work has been the determination of the thickness of the alluvial deposits of each terrace, with a view to constructing the length-profiles of the sub-alluvial benches. In view of the limited number of tributary channels dissecting the terraces, and the burial of the base of terrace-deposits by the alluvium of the next terrace below, it was generally only possible to determine the thicknesses along the present channel of the river, at the few points where each terrace is being actively undercut. The rather scanty data that could be collected have, however, assisted in the interpretation of the history of the river.

Length-profiles of the terraces were prepared in the field as spot-heights were determined. These profiles served the dual purpose of facilitating the correlation of subsequently determined terrace-remnants and of detecting gross errors in determination of heights.

The Identification of Principal Terraces and their Representation in the Form of Length-Profiles.

In the study of river-terraces it is necessary to distinguish unpaired terraces, formed during periods of simultaneous lateral and vertical erosion, from those whose upper surface formerly constituted a flood-plain of more or less stable form, graded to a sea-level that remained stationary for an appreciable length of time. Terraces of the latter type have been called "principal terraces" (Steers, J. A., 1937, p. 235). The same author suggests that the most satisfactory method of recognising principal terraces would seem to be from their accordance of height all down the valley (1937, p. 235).

This method has been applied in the present investigation, the degree of accordance being determined by length-profiles. The profiles of Pl. XI were constructed by plotting terrace-heights against distances measured along the present course of the river. It is important to notice that the line of reference for the measurement of horizontal distances is a purely arbitrary one, and that the gradients of the profiles might be very different for other reference lines. For instance, if a line midway between the outer bounding escarpment is selected, the value of the gradients is increased, on the average, by 25 per cent. Similarly, assuming that the river had, formerly, a much more sinuous course, and that that could be determined, its selection as a reference line might reduce the gradients of the corresponding terrace-profile by as much as one half. It is obvious therefore that the importance of the gradients of the profiles of Pl. XI is limited. On the other hand the true difference in height between successive terraces is preserved at all points.

In the present instance each of the terrace-profiles has been plotted with reference to at least two, and in some cases three, arbitrary reference lines, before the final correlations were accepted. In the case of the Harveyton terrace (see p. 362) the highest degree of accordance to a smooth curve, of decreasing gradient downstream, was obtained when heights were plotted against distances along the median line between the outer bounding escarpments. This profile was particularly useful, for it showed clearly that the highest levels between Addo Drift and Hermitage (see profiles) lie above the level of the profile of the Harveyton terrace, a fact which is not so obvious when the profile of the latter terrace, as drawn in Pl. XI, is extrapolated upstream from Zoetgeneugd.

The Correlation of the Terraces.

The present investigation reveals the existence of four principal terraces, with a maximum difference of height of 120 feet between the highest terrace and low-water level of the river. This maximum occurs about Barkly Bridge, while near the sea the highest terrace stands at approximately 100 feet above low-water level, and at Courans Drift at about 50 feet above it. For convenience of description they have been designated, from highest to lowest, the *Kirkwood*, *Harveyton*, *Addo*, and *Colchester* terraces respectively, each after a locality in which it is well represented. All four lie above the present flood-plain, and their distribution is shown on the accompanying map, Pl. XI.

In the following discussion the terraces will be treated collectively; the description is arranged regionally, working upstream from near the mouth. In view of the peculiar features of the highest terraces in the Addo

district, the discussion of the correlation there is deferred to the end of this section.

In their correlation the Colchester terrace provides a readily distinguishable datum from the fact of its almost universal occurrence within half a dozen feet above the maximum level of flood-waters of at least the last two decades. When spot-heights on it are plotted against distances measured along the present channel they approximate very closely to a smooth curve of regularly decreasing gradient downstream, a fact which confirms its recognition as a principal terrace. About Mackay Bridge its length-profile becomes noticeably convex upwards, a phenomenon that may be due to greater width of the channel, in Colchester time, at its seaward extremity, as is the case at the present time (see p. 358). As far upstream as Summerville Estates, at least, this terrace cannot be confused with either the Addo terrace above it or the flood-plain below.

From Zoetgeneugd almost to the sea, a high terrace, the Harveyton, occurs more or less continuously on one or other side of the river. The level character of its transverse profile, the smoothness of its length-profile, its extent both longitudinally and transversely, and its clear distinction in height from any other terrace, stamp this as a principal terrace. Near Barkly Bridge, and on Zoetgeneugd, a further terrace, the Addo, makes its appearance for the first time upstream from the sea, between the level of the Colchester and Harveyton terraces.

Between Sunlands and Landdrost Vee Plaats an extensive and, for all practical purposes, continuous high terrace occurs on both sides of the river, at about 70 feet above low-water level. Like the Harveyton terrace of the lower reaches, this feature is extensively developed and sweeps across the whole width of the alluvial tract to the foot of the outer bounding escarpments. This and its height above the river suggests that it is probably the equivalent of the Harveyton terrace, and, as is shown below, this is supported by the evidence of the intervening region on Commando Kraal Estate. In further confirmation the Addo and Colchester terraces, as elsewhere, less extensive in their development than the Harveyton terrace, occur in their appropriate positions.

In the neighbourhood of Landdrost Vee Plaats, however, a terrace distinctly higher than the Harveyton is represented by two small remnants, one of which occurs on the west side of the valley near the mouth of the Bezuidenhouts River. This, though separated from the Harveyton terrace by the present channel of the Sundays River, clearly overlooks that terrace by some 20 feet. The other, on the east side of the valley, occurs on Landdrost Vee Plaats at the outer edge of the Harveyton terrace and is separated from it by a distinct, sloping surface, though the original scarp-face between the two seems to have been smoothed out by soil-wash.

Upstream from this locality the higher of the two terraces is the more extensive.

At Kirkwood, and for a considerable distance above and below it, a high terrace, standing at 70 feet above low-water level, is extensively and continuously developed. The slope of its length-profile suggests that this is to be identified with the terrace remnants, in the neighbourhood of Landdrost Vee Plaats, lying above the level of the Harveyton. This is confirmed in the region between by the recognition of *three* lower terraces, falling into place as the equivalents of the Harveyton, Addo, and Colchester terraces. All four can be recognised in a transverse section along the road from Addo to Kirkwood after it crosses the river into Kirkwood itself. Because of its extensive development in this region the higher terrace is called the *Kirkwood*.

As stated in the previous paragraph, where the road from Addo crosses the river into Kirkwood all four terraces are present, but a little more than a mile upstream a significant change takes place in that the number of terraces, up to and including the Kirkwood, is reduced to three. In the region between an appreciable increase in the gradient of the river-bed takes place with the result that, whereas the Kirkwood terrace stands at about 70 feet above low-water level of the river, below Kirkwood it stands at only 50 feet above it on the upstream side of the town. The Kirkwood terrace slopes continuously, and apparently uniformly, across the zone of increased river-bed gradient. From the field relationships and from the length-profiles, the Harveyton and Addo terraces can be correlated across this zone also, so that it is clear that either the Colchester terrace or the flood-plain of the lower reaches is eliminated at this point. Since the present river-bed is not incised below the level of the base of the Colchester terrace, as is described on p. 359, it would seem that the steepening of the low-water profile, at Kirkwood, occurs at a nick-point developed in the Colchester and not the present cycle. In view of this it is highly probable that the upper surface of the Colchester terrace is continuous, above the nick, with that of the Addo terrace. The alternative suggestion, that the former is continuous, above the nick, with the present flood-plain, seems improbable, for it implies that the Colchester rejuvenation worked upstream to a nick-point in the bed-rock profile and yet was accompanied by rejuvenation, to form a new flood-plain, above the nick. It has not been possible to follow the Colchester terrace through to one or the other, in the field, but the correlation with the Addo terrace seems the more probable. It is interesting to note that only recently the coincidence of nick-points in sub-alluvial benches with nick-points in upper surface profiles has been recorded as occurring no less than four times in the flood-plain of the Thames (Day Kimball, 1942, pp. 25–26). The correlation adopted above introduces a problem of terminology, the Addo flood-plain, above

the nick, being, in its later stages, synchronous with the Colchester cycle. It seems best to retain the title *Addo Terrace* for the feature above the nick, since it is regarded as continuous with that terrace below the nick.

The recognition of the Kirkwood as a terrace quite distinct from the Harveyton explains the features of the region about Addo. Here, on Commando Kraal Estate the Colchester and Addo terraces can be readily recognised by their height and extent, but the two higher terraces can only be recognised, or distinguished, when the sequence at Kirkwood is appreciated. On the east side of the river, on Commando Kraal, occurs a very extensive and continuous, though not quite level, surface, that sweeps across the valley from the foot of the eastern bounding scarp to points at a lower level, near the river, where it overlooks the Addo and Colchester terraces. The outer parts of this feature stand 20 feet or more above the level of those near the river. At one point only has the writer noticed a slight scarp in the surface of this feature, suggesting that two terraces are represented by it. For the most part the change in altitude is gradual. Interpretation is made more difficult by a broad, shallow valley that traverses the feature along the line of the railway. If two terraces are represented here it is impossible to decide, on the evidence available, whether the slope of the surface is due to slip-off of meanders or to the obliteration of a former scarp by soil-wash. However, it is significant that the highest elevations accord well with those to be expected from a downstream extrapolation of the Kirkwood terrace-profile, while the lowest elevations fall into place between the upstream and downstream portions of the profile of the Harveyton terrace. The high terrace on the west bank at Addo Drift is correlated with the Kirkwood terrace by reason of its height and the limited thickness of its alluvial deposits. This is described more fully in a later section.

Description of Terraces.

The Kirkwood Terrace.—This terrace represents a former flood-plain which attained a breadth of 2 miles not far below Courans Drift, $2\frac{1}{2}$ miles near Dunbrody, and 3 miles on Commando Kraal Estate. Its upper surface is remarkably level in transverse profile, though subsequent soil-wash has given rise to a gentle and, in places, broad slope at the foot of the outer bounding scarps.

In common with other terraces this one is built up largely of alluvium, resting on a relatively thin gravel and boulder-bed. The latter contains boulders of a variety of rocks but principally of quartzite. The following is a summary statement of the nature and thickness of the deposits in undercut sections. Cretaceous rocks are exposed at the base in all cases.

Locality.	Alluvium.	Boulders.
1 mile below Kariega confluence, South bank . .	22 feet	3 feet
1 mile above Cleveland Weir, North bank . . .	22 feet	3 feet
Cleveland Weir	15 feet	10 feet
Confluence of Bezuidenhouts River, South bank .	20 feet	5 feet
Addo Drift	15 feet	3 feet

Below Addo Drift the Kirkwood terrace has disappeared almost entirely, but it may be represented on the farm Melville (see Pl. XI). Here occurs a narrow ledge with a thick capping of tufa, whose upper surface stands at about 120 feet above sea-level, 2 miles from the present shore. The surface of the ledge has a slight slope towards the river and in this respect resembles the marginal parts of the Kirkwood terrace in its upstream occurrences. At the edge of the terrace an extensive quarry has been opened in the tufa which can be seen to rest on a soft-weathering, green sandstone, at a height of 100 feet above sea-level. It is possible that this is an altered Cretaceous sandstone. It is not possible to determine the former level of the Melville bench at places nearer to the centre of the valley. The Harveyton terrace occurs immediately below the bench, at 60 feet above sea-level.

An examination of the map, Pl. XI, shows that the bulk of the erosion of the Kirkwood terrace was effected in the Harveyton cycle * of river development, for, where the Kirkwood terrace is absent, the Harveyton terrace generally, though not invariably, occurs at the foot of the outer bounding scarps. The position of the outer scarps seems to have altered little since Harveyton time.

The Harveyton Terrace.—The flood-plain of Harveyton time probably attained a breadth of well over 2 miles in the seaward part of the valley. Its average width above Barkly Bridge was about 1½ miles. Except in the lowest reaches, and near Dunbrody, the river failed to remove the earlier Kirkwood terrace at this time.

A summary statement of the nature and thickness of the Harveyton deposits is given here. Boulders, when present, occur at the base.

Locality.	Alluvium.	Boulders.
Landdrost Vee Plaats	20 feet	3 feet
Summerville Estates, northern part	48 feet	Nil
Near Coerney confluence	about 36 feet	4 feet
Zoetgeneugd	60 feet	Nil
Near Barkly Bridge . .	probably between 60 and 85 feet	Unknown
1½ miles north of Fascadale beacon .	(between) 65 and 85 feet	Unknown

* The term *cycle* is employed here as a convenient term for the collective description of the events of the period of time beginning with the conversion of a flood-plain into a terrace, by rejuvenation, and terminating at the time of the rejuvenation which produced the next succeeding terrace. The cycle is arbitrarily named after the terrace which came into being as a result of the terminating rejuvenation.

In the two last localities the higher figure is based on the occurrence of Cretaceous rocks, close to the edge of the Harveyton terrace, but beneath the deposits of later terraces. North of Fascadale beacon 65 feet of alluvium is exposed below the top of the terrace. The figure of 60 feet for Barkly Bridge is based on the assumption that the deposits there are comparable with those north of the beacon. Cretaceous rocks are exposed at the base of the other occurrences, except that on Landdrost Vee Plaats where, however, it is probable that the boulders are not much thicker than the 3 feet observed. The increase in thickness of the deposits, downstream, is very noticeable.

The most interesting remnant of the Harveyton terrace occurs 2 miles from the sea, at the point where the river turns abruptly through a right angle into its final straight reach to the sea, east of Colchester village. This is mentioned by Dr. A. V. Krige (1927, p. 32), who correlates it with his "Major Emergence". In marked contrast to the alluvium and boulder-bed so characteristic of the upstream occurrences, the terrace is here built up very largely of consolidated beach- and dune-sands. At the bend in the river the terrace is being undercut and a complete sequence from sea-level to its upper surface is exposed. At the base occurs 9 feet of mottled brown, green and blue, laminated, and gypsiferous clays. Overlying these, to the top of the terrace, are white and buff, flaggy sandstones, partly horizontally and partly cross-bedded. Two feet six inches above the base of the sandstone occurs an intercalation of clays, similar to those beneath, and a little over one foot in thickness. The mottled clays bear a striking resemblance to those of the Uitenhage Series, but in the absence of fossils there remains an element of uncertainty as to their age. The following observations suggest that they may be of Pleistocene age. The contact between them and the sandstone was exposed by the floods of 1944 over a distance of about 150 yards, along the bank of the river. An examination of this revealed no sign of a disconformity or pebble-bed between the two. The sandstones, at least, are quite unlike those of the Uitenhage Series, and their field relationships show that they are the remains of a formerly extensive deposit in an embayment of the eastern bounding escarpment, of Cretaceous and Tertiary rocks, of the Sundays River valley. In the kloof on Zoekamma and Vetmaak Vlakte they occur at heights well below the level of the base of the Alexandria Formation, presumably banked up against the Cretaceous rocks of the valley sides. It is clear that this kloof was cut deeply into both the Uitenhage Series and the Alexandria Formation, filled with sand, and subsequently re-excavated. North of the kloof the field relationships of the sandstones and the high bounding escarpment of Cretaceous and Tertiary rocks leaves no room to doubt that the latter had been eroded back to its present position, before the deposition of the sandstones. In

view of these facts it can be confidently concluded that the sandstone post-dates the bulk of the Alexandria Formation and that it is probably of Pleistocene age. It would indeed be remarkable if the mottled clays at Colchester proved to be of Cretaceous age, separated from the overlying Pleistocene sandstones by an extensive erosional surface with no signs of disconformity. It is possible therefore that the clays are lagoon deposits of Pleistocene age and that the flaggy and horizontally bedded sandstone, at the base of the overlying sandstones, represents the advance of shore deposits across the muds of a shrinking lagoon. At this time the sea was, presumably, little, if at all, below its present level, and was perhaps as high as 9 feet above it. At a later date the lagoon clays were buried beneath 40 feet or more of wind-blown sand.

The upper surface of the sandstones forms a broad terrace at about 60 feet above sea-level, presumably owing its origin to truncation by the sea, though no clear proof of this has been noted to date. The seaward margin of the terrace is overlain by recent unconsolidated sands to a height of 80 feet above sea-level. The terrace may be regarded as contemporaneous with the Harveyton river-terrace, which stands at the same altitude (60 feet), at the same distance from the sea, on the farm Melville. In anticipation of a later section it may be said that the lower level of sea-level recorded at Colchester agrees well with the length-profile of the sub-alluvial bench of the Harveyton terrace.

The Addo Terrace.—This terrace has a much smaller lateral development than the earlier ones, its width varying between a little more than a mile and a few hundred yards. At two points in particular, on Zoetgeneugd and on the south part of Tragaron, it is conspicuously reduced in width where the migration of meanders has been restricted in undercut amphitheatres of the high bounding escarpments of the Lower Terraces. Downstream from Barkly Bridge not a single vestige of a river-terrace, or other morphological feature, with which the Addo terrace can be correlated, has been recognised.

Above Kirkwood the terrace-deposits are 25–30 feet in thickness and their base lies close to the present low-water level of the river. A boulder-bed is occasionally exposed at the base of the alluvium. Below Kirkwood only three undercut sections are exposed. At Addo, a thickness of 40 feet of fluviatile deposits is exposed, of which the upper 20 feet is alluvium and the lower 20 feet boulders with a thin intercalation of alluvium. The base of the deposits stands about 20 feet above low-water level. On the west bank, opposite the Mission Station on Geelhoutboom, 32 feet of alluvium overlie 2 or 3 feet of boulders, resting on Cretaceous rocks at 20 feet above low water, while, at the causeway, a little less than one mile upstream, 40 feet of fluviatile deposits rest on Cretaceous rocks at 10 feet above

low-water level. Here a thick, wedge-shaped mass of boulders, varying rapidly in thickness from 20 to 30 feet, constitutes the lower part of the deposit and is overlain by alluvium. The boulder horizon becomes thinner away from the Witte River, which appears to have been responsible for the local thickening of it. In all three localities the base of the deposits of the Addo terrace lies some 20 feet below the base of those of the Harveyton terrace. As far as can be judged from the limited exposures, the deposits are comparable in thickness with those of the Colchester terrace at most places, but appear to be somewhat thinner than those of the Harveyton terrace about Addo.

The Colchester Terrace.—This terrace is a continuous feature for several miles downstream from Barkly Bridge, and terminates at 15 feet above sea-level at the bend in the river at Colchester. Seaward of the farm Harveyton the terrace has a distinctly convex transverse profile. In this part of the valley broad levees flank the channel, and broad sloughs, some 5 or 10 feet lower than the levees, occupy the margins of the terrace. The position of the sloughs is shown on the accompanying map, Pl. XI. A number of tributaries, normally dry, debouch into these, and their junctions with the main stream are thus deferred. An interesting feature of the terrace is the steepening of the gradient of its length-profile between Mackay Bridge and Colchester (see profile, Pl. XI). In the same locality the present channel shows a gradual increase in width until at Colchester it is more than half as wide again as it is at Mackay Bridge. It seems probable therefore that the increased gradient of the Colchester terrace is, in part if not wholly, due to reduction in height of flood-waters consequent upon greater width of the channel. The explanation remains a possible one even in the absence of proof that the channel varied in width in the same manner in Colchester times. It is interesting to notice that at the present time the comparatively large waves thrown up in the long, straight reaches between the sea and Mackay Bridge, supplemented by tidal- and river-currents, are rapidly undercutting, and removing collapsed portions of, the river banks, and thus maintaining, if not perhaps increasing, the width of the channel. This process does not seem to be taking place above Mackay Bridge to anything like the same extent.

Upstream from Barkly Bridge the convex transverse profile is replaced by the more usual level profile, terminating laterally and fairly abruptly against the scarp-edge of the earlier terraces. However, near Barkly Bridge and Sunlands there is a gradual change in height from the level of the Addo to the level of the Colchester terrace, probably representing the slip-off of meanders during rejuvenation.

Practically everywhere above the tidal reaches, which terminate at Barkly Bridge, the terrace-deposits consist largely of alluvium, which,

where the base is exposed, rests on 2 or 3 feet of boulders at low-water level. Occasionally the boulders are absent and the deposits entirely of alluvium. Their total thickness increases downstream from 30 feet, in the reaches above Sunlands, to 40 feet near Hermitage Siding, and to 50 feet below Addo. The only information concerning the level of the base of the deposits below Barkly Bridge is afforded by the boreholes at Mackay Bridge (see p. 364). For the greater part of the course of the river the Cretaceous bed-rock is not exposed beneath the terrace, but the frequent occurrence of Cretaceous rocks in the channel shows that the present river-bed closely approximates to the base of the terrace-deposits. Exceptionally, as at Addo Drift and Sunlands, Cretaceous rocks rise as much as 10 feet, or more, above low-water level in undercut faces of the Colchester terrace, possibly due to slip-off during rejuvenation and subsequent intersection at a lower level by the present course.

The Flood-Plain.—The channel of the river is everywhere flanked on one side or the other, sometimes on both sides, as at Barkly Bridge, by a narrow alluvial terrace, which, above Mackay Bridge, occurs at 20 to 25 feet above low-water level. Below the last-named locality, and like the Colchester terrace, this lower feature decreases in height until, at the bend at Colchester, it stands only 9 feet above mean tide-level. In the last mile to the sea it occurs on the north bank as a transversely level feature, perhaps 200 yards in width, decreasing in height from about 7 feet above mean tide-level to little more than 3 feet above it near the shore. At least four major floods in the last fifteen years have submerged this feature, almost to the level of the Colchester terrace; that is to a depth of some 20 feet above the upper surface of the bench in the reaches above Mackay Bridge, and to a depth of 3 or 4 feet at Colchester. This periodically inundated alluvial terrace is here described as "the flood-plain", though it is not everywhere plane in transverse profile. The flood-plain rarely exceeds 100 yards in width, being generally much less than this, and its upper surface is variable in form; sometimes it is distinctly level, at other times descends in steps towards the river, sometimes slopes unevenly towards the river, or again, is quite irregular in form. It terminates at the foot of a distinct scarp at the edge of the Colchester or earlier terraces. The descent to the low-water level of the river is frequently abrupt. At Colchester the action of waves and currents maintains an almost perpendicular bank between the river and the flood-plain, between floods, and it is possible that similar abrupt terminations of the flood-plain, in the higher reaches, may be partly due to erosion during periods of mild spate. At some localities the level portion of the flood-plain is separated from the river by a gradual, though uneven, slope of sand and boulders. The flood-plain is characteristically developed on the inside of meander-curves, facing an undercut terrace on

the opposite bank, though, as noted above, it occasionally occurs on both banks. An opportunity was taken to visit the river shortly after two recent floods. In those localities visited the river left a deposit of silt on the flood-plain possibly not more than a few inches thick, on the average, but as much as 2 feet thick where the flow was arrested, on the downstream side of clumps of bush, low shrubs and grass. The many eye-witnesses of the floods of the last two decades are unanimously of the opinion that present-day floods do not overflow the Colchester terrace, but at most points they rise to within 5 feet of it. The statement that the Colchester terrace has not been flooded in recent floods needs to be qualified to the extent that the marginal sloughs of the lower reaches have been flooded from the points where they intersect the present channel.

The Alluvial Deposits and their Bearing upon the History of the River.

Where boulder-beds occur beneath the alluvium of the terraces, they are generally about 3 feet in thickness. Of the localities where this thickness is greatly exceeded, in the Kirkwood terrace at the Cleveland Weir, and in the Addo terrace at Addo and Dunbrody, the greater thickness of boulders at the first- and last-mentioned localities seems to be due to the confluence of strong tributaries with the main stream. The reason for the exceptional thickness at Addo is unknown.

The present channel of the river is strewn with boulders, particularly at the confluence of the larger tributaries and where older boulder-beds are being undercut. With the migration of meanders these boulders are destined to be buried beneath alluvium on the inner, convex, bank. That this is taking place at the present time is witnessed by the frequent occurrence of boulders at the base of the alluvium in the present flood-plain.

Throughout the period covered by the Lower Terraces the channel of the river must have been supplied with boulders, from tributaries or from the undercutting of older terraces, and the burial of these beneath alluvium, in successive cycles, is a phenomenon which does not, of necessity, require explanation in terms of changing climate, or of earth-movements. The boulders and overlying alluvium of each terrace are probably pene-contemporaneous deposits resulting from meander-migration.

Interpretation.

The Kirkwood and Harveyton Terraces and their Sub-Alluvial Profiles.

Pl. XI shows the profiles of the Kirkwood and Harveyton terraces and the approximate form of the profile of the sub-alluvial surface of the

Harveyton terrace. On it are plotted the positions of points which have been used to determine this sub-alluvial profile. It will be noticed that only four of these can be accepted as representing the true level of the surface in question. The remaining points are located on the upper surface of the Cretaceous rocks beneath the alluvium of later terraces. The construction of the profile clearly rests on the assumption that a significant degree of planing of the valley-floor was effected in the Harveyton cycle. In view of the breadth of the Harveyton terrace, on the average about 2 miles, the limited amount of vertical incision in the course of the cycle, on the average about 40 feet, and the fact that no residual masses of Cretaceous rocks protrude through the relatively thin cover of alluvial deposits, there can be little doubt that such planing took place. Confirmation is afforded by the approximation of the profile to a concave-upward curve of decreasing gradient downstream.

Also plotted are the levels of two points on the sub-alluvial surface of the Kirkwood terrace at Addo Drift and the mouth of the Bezuidenhouts River. It will be seen that both of these lie at a distinctly higher level than the sub-alluvial surface of the Harveyton terrace in the same localities. This fact in itself does not indicate the relative age of the two surfaces. However, if the cutting of the Kirkwood sub-alluvial bench post-dated that of the Harveyton, we should expect to find a boulder horizon in the Harveyton deposits corresponding to the position of the channel during the period of formation of the Harveyton flood-plain. Since this does not occur, it is probable that the Kirkwood sub-alluvial bench is older than the Harveyton.

A comparison of the profiles of the upper and lower surfaces of the Harveyton deposits shows that the deposits increase in thickness downstream from the neighbourhood of Landdrost Vee Plaats. Only 2 miles from the present shore the upper surface stands 60 feet above the lower one, so that an upward movement of the strandline probably followed the cutting of the sub-alluvial bench. If so, the Harveyton deposits below Landdrost Vee Plaats constitute an alluvial nappe (Steers, J. A., 1937, p. 234). The considerable degree of erosion of the earlier Kirkwood terrace was probably effected in the episode of rejuvenation to the level of the Harveyton sub-alluvial bench. It is possible that the river was at this time cutting into a valley-fill even older than the Harveyton.

One other feature of the closing stages of the Harveyton cycle is worthy of mention, if only for the field of inquiry that it opens up. The map of Pl. XI shows that the alluvial strip of the Addo terrace pursues a fairly direct course down the valley. Thus, for instance, from the point on Landdrost Vee Plaats where it abuts against the northern bounding scarp the terrace swings in a broad, open curve across the valley, only returning to the northern scarp at a distance of 7 miles downstream, on Tregaron.

Below this point, after returning to the southern scarp and remaining close to it for a number of miles, the terrace returns to the northern one at Addo, 10 miles below Tregaron. Since the course of the river at the end of Harveyton time must have been within the limits set by the Addo terrace, it seems that, at that time, it pursued a fairly direct course through its flood-plain. This is most noticeable at, and below, Dunbrody. It is interesting to speculate on the possibility that the comparative straightness of the channel is the result of the aggradation of late Harveyton time. The phenomenon of meander shrinkage, which may be regarded as a manifestation of the process of channel-straightening, is well known and may be brought about by a number of processes which cause a reduction in the volume of flow (Davis, W. M., 1913). In this instance the suggestion is offered that a similar result may be brought about by aggradation, enforced by rise of sea-level. That channel-straightening did in fact take place cannot be conclusively demonstrated, though, as pointed out on p. 361, a considerable degree of planation was effected in the earlier stages of the Harveyton cycle, a phenomenon that may be attributed most readily to the free swing of meanders at that time. In any case the suggestion is one that might profitably be the subject of more detailed investigation, for, if valid, it offers a useful means of detecting upward movements of the strandline. It is interesting to notice that aggradation, caused by *channel-plugging*, has been described recently by Happ, Rittenhouse and Dobson (1940) in certain valleys in the United States. The present channels of the affected rivers are noticeably straight, though the authors do not discuss the possibility of a formerly more sinuous course. In this instance the aggradation was accompanied by the growth of levees, which, in my opinion, would play a critical rôle in the process of channel-straightening. On purely theoretical grounds a sequence of channel-aggradation, levee-formation, breaching of levees, and channel-straightening may be deduced as a result of the species of channel-plugging brought about by a rise of sea-level. In the case of mature rivers of low gradient the process may be operative for some miles upstream.

The Addo and Colchester Terraces.

These terraces may be considered together. The profiles of Pl. XI show that, as far downstream as Addo, or Barkly Bridge, the Colchester, Addo, and Harveyton terraces diverge in a downstream direction. Below Barkly Bridge the Colchester terrace assumes a very gently sloping length-profile and converges upon, though not intersecting, the Harveyton terrace. Seaward extrapolation of the Addo terrace, on an arbitrary basis, suggests that it, too, converges upon the Colchester terrace and may, in fact, intersect

it in the neighbourhood of Mackay Bridge. Analysis of these facts suggests that the cycles were of successively shorter duration, so that in each the river failed to reduce the gradient of its flood-plain to that of the preceding cycle. The fact that the terraces survived over wide areas supports this view. Explanation of the phenomena in terms of epeirogenic movements involves a more complex series of events, in view, on the one hand, of the downstream divergence of the profiles above Barkly Bridge and, on the other hand, of the comparatively steep upper surface profile of the Harveyton terrace and the gentle profile of its sub-alluvial bench in the lowest reaches. In so far as the profiles may have been influenced by climatic changes, the most significant feature appears to be the steepness of the Harveyton terrace profile in its seaward parts, suggesting that in Harveyton time the relationship between load, or calibre, and transporting power was such as to necessitate the establishment of the graded profile at a fairly steep angle. This condition may be due to smaller volume of flow, perhaps occasioned by a relatively low rainfall, in Harveyton time.

Information concerning the progress of the Addo cycle is scanty.

The great thickness of boulders at Addo, and perhaps, in part, those at Dunbrody, may bear witness to an episode of aggradation, due, possibly, to climatic or tectonic phenomena, in the late stages of the cycle, but no confirmation of this is yet available.

In the course of the succeeding Colchester cycle, the Addo terrace was eroded over wide areas, particularly below Barkly Bridge. In view of the few tributary streams that could have assisted in this process it seems probable that it was largely effected by migrating meanders of the Sundays River itself. It is significant, therefore, that while the meanders of Colchester time are still recognisable, though entrenched, at and above Addo, yet below Barkly Bridge the present course of the river, little altered from its position at the end of Colchester time, is remarkably straight. This, and the convex transverse profile of the Colchester terrace in the same reaches, suggests that the cycle was terminated by an episode of aggradation, affecting principally, and perhaps exclusively, the lowest reaches.

The Flood-Plain.

The most significant feature of the flood-plain is its occurrence above, as well as below, the nick-point in the Colchester cycle. This shows clearly that it owes its origin to change in volume or rate of flow, rather than eustatic change of sea-level. The fact that the flood-plain is submerged to a depth of 20 feet during major floods indicates that the present cycle is one of rejuvenation, deposition being delayed until an advanced stage in the subsidence of flood-waters. The fact that the river has failed to overflow

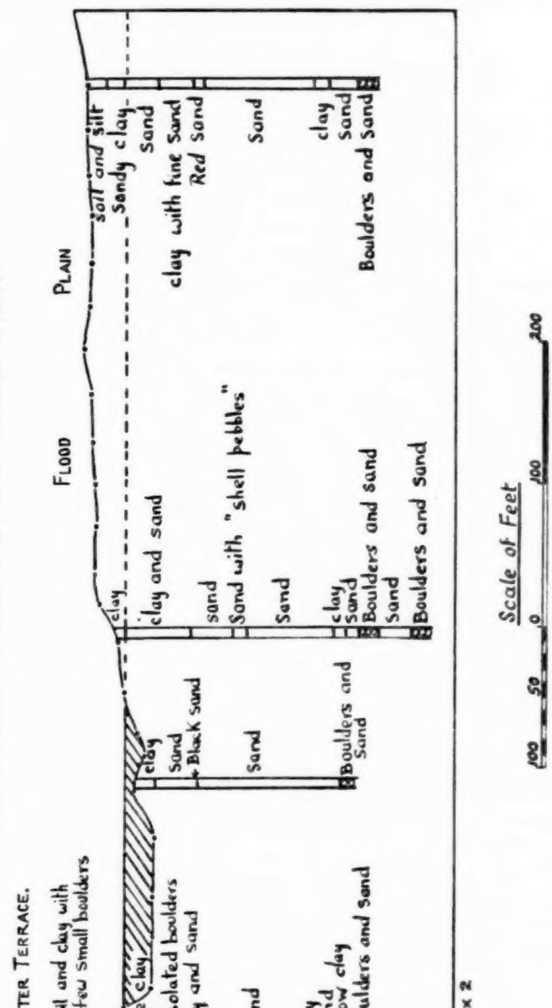
the Colchester terrace in the major floods of recent years is not incompatible with an increase of volume; the first effects of such rejuvenation must be the acceleration of erosion on the concave banks of meanders and the retardation of deposition on the convex banks. The river would in this way be accommodated in a channel of larger cross-section area than formerly.

The inferred increase of volume, or rate of flow, offers an explanation of the fact that the comparatively narrow channel of the river is tidal for no less than 10 miles along its course, as far as Barkly Bridge. As long ago as 1905, Mr. C. W. Methven suggested that the tidal reaches of South African rivers are swept clear of wave and tide-transported debris during floods, and, further, that the matter transported by the river is itself swept out to sea and produces little change in the tidal reaches (1905, p. 212). These conditions appear to apply to the Sundays River at least.

It is possible that rejuvenation by fall of sea-level has affected the lowest reaches (see p. 368). The small rapids at Addo Drift may represent the head-point of such rejuvenation, but more information is required. This possibility in no way affects the preceding conclusion.

The Boreholes at Mackay Bridge.

The writer is indebted to Mr. Pickford, District Roads Engineer, for the details of the text-figure, which shows the records of four boreholes, sunk at intervals of 100 to 400 feet across the channel and flood-plain of the Sundays River, at Mackay Bridge. Though the boreholes cover only a small proportion of the total width of the valley the records are nevertheless of considerable interest. The holes were sunk in each case through a sedimentary fill of clay and sand, with occasional small pebbles, down to depths between 84 and 112 feet below low tide-level. In all four holes a boulder-bed, some 8 to 10 feet in thickness, was encountered between 80 and 84 feet below low tide-level. In one hole a second boulder-horizon was encountered about 12 feet lower, but the remaining holes were abandoned at the level of the higher boulder-horizon. In view of the proximity of Mackay Bridge to the sea the boreholes provide evidence of a former sea-level at least as low as 112 feet below low tide-level, recalling the well-known buried channel of the Buffalo River at East London, of which the deepest parts, nearer to the sea than the Mackay Bridge, occur at −124 feet (Schwarz, E. H. L., 1907). In the Mackay Bridge section the bulk of the sediment below −20 feet is sand, while above that level clay is common. In the absence of a definite boulder-horizon in the higher levels of the holes it is difficult to determine whether or not a disconformity exists above the base of the higher of the low-level boulder-horizons. The most that can be inferred concerning the age of the low-stand of the sea is that it occurred before the final stages of the Colchester cycle.


SECTION ACROSS THE SUNDAYS RIVER AT MACKAY BRIDGE.
FEET
COLCHESTER TERRACE.
FLOOD PLAIN
20
10
L.T.L.
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Soil and clay with few small boulders
Blue clay
Isolated boulders
Clay and sand
Sand
clay
Sand
Yellow clay
Boulders and Sand
clay
Sand
Black Sand
Sand
Boulders and Sand
clay
clay and sand
sand
Sand with "shell pebbles"
Sand
clay
Sand
Boulders and Sand
Sand
Boulders and Sand
Soil and silt
Sandy clay
Sand
clay with fine Sand
Red Sand
Sand
clay
Sand
Boulders and Sand
V.E. × 2
Scale of Feet
100
50
0
100
200

TEXT-FIGURE.

The Record of Former Sea-Levels.

For a number of reasons the sea-levels corresponding to the terraces and sub-alluvial benches cannot be determined precisely. Principal among these is the difficulty of determining the position of the mouth of the river for each cycle. In general the position of the shore of Algoa Bay seems to have approximated fairly closely to the line of intersection of the sea-level plane with the sloping plain capped by the Alexandria Formation. On this basis the shore of the bay probably lay about one mile landward of its present position when the sea stood 100 feet above its present level. Of delta building, seaward of the shore of the bay, there remains no trace to-day, in spite of the fact that the history of the period under discussion has been predominantly one of emergence, a condition which would tend to minimise the power of wave attack. In the period under discussion the amount of cliffing of the adjacent shore of Algoa Bay appears to have been quite small, and the broad belt of coastal dunes, in places 2 miles wide, suggests that the dominant shore-line process has been the throwing up of sand, by waves, and its subsequent landward migration as dunes. In view of this it is probable that the river has at no time built a delta to any significant extent beyond the present shore of Algoa Bay, for, had it done so, it is probable that some traces of it would remain. The exposed parts of the Colchester and Harveyton terraces are fluviatile throughout, so that at the close of those cycles the mouth of the river lay, at most, 2 miles landward of the present shore. A landward limit for the position of the mouth in Kirkwood and Addo time cannot be determined.

The bench on Melville, at 100 feet, provides a convenient upper limit for the sea-level of Kirkwood time, unless we postulate a remarkably low gradient for the terrace. On the other hand, since the bench cannot, with certainty, be correlated with the Kirkwood terrace, a lower level of the sea is possible. If, as seems probable, the Kirkwood profile was not steeper than that of the Harveyton terrace, in the lower part of the valley, the original position of the Kirkwood profile, on Melville, would be not less than 80 feet above sea-level. The figures of 80 and 100 feet may be accepted with some confidence for the limits between which the sea-level of Kirkwood time lay.

The sub-alluvial profile of the Harveyton terrace includes, at its seaward extremity, the top of the lagoon clays, overlain by shore- and dune-sands, of the terrace of Colchester. As suggested on p. 356, the passage from clays to sands, at about 10 feet above mean tide-level, seems to be due to the advance of shore- and dune-sands over the muds of a lagoon, so that the level of the sea at this time was probably not more than 10 feet above its present level and probably not more than a few feet, if at all, below the top

of the clays. The level of the bottom of the clays is not known, but they occur at least as low as present sea-level.

The profile of the upper surface of the Harveyton terrace, in the lowest reaches of the valley, has a gradient of approximately 4 feet per mile, and the terrace is almost continuously developed as far downstream as Melville, where it stands at 60 feet above sea-level, 2 miles in a direct line from the present shore, and perhaps little more than a mile from the shore of Algoa Bay, in late-Harveyton time. The nature of the terrace-deposits on Melville is not known, but on Tankatara the upper part at least, above 60 feet above sea-level, is fluviatile. The truncation of the sands of the terrace at Colchester suggests that in late-Harveyton time the sea reached close on 60 feet above its present level, a conclusion in agreement with the evidence of the length-profile of the Harveyton terrace. Assuming that the shore lay to seaward of the farm Melville, and allowing some reduction in gradient as the shore is approached, extrapolation of the profile suggests that at most the sea stood not lower than 40 feet above its present level. A figure nearer to 60 feet seems more probable for the actual level.

The sea-level of Addo times can only be placed within wide limits. Downstream extrapolation of the terrace profile, on an arbitrary basis, suggests a most likely level in the neighbourhood of 20 feet above present sea-level. The actual level may, however, have been as much as 20 feet above or below this.

The Colchester terrace terminates at Colchester at a height of 15 feet above mean tide-level. About 800 yards downstream the upper surface of the alluvial floor of a left-bank tributary, on the farm Vetmaak Vlakte, stands at 14 feet above mean tide-level and 5 feet above the immediately adjacent flood-plain of the Sundays River. If, as seems probable, the valley-floor at 14 feet is the chronological equivalent of the Colchester terrace, we have reason to suppose that the sea-level of late-Colchester time was perhaps as high as 12 feet above its present level. The evidence is, however, far from conclusive, and the sea-level of late-Colchester time may have been the same as at present. Dr. L. C. King has suggested to the writer that the Addo and Colchester terraces may have been graded to the same sea-level, the intervening rejuvenation being due to landward advance of the shore under wave attack. This is possible, but the coastal features suggest that no appreciable migration of the shore has taken place in the period concerned.

The Mackay Bridge boreholes show that prior to late-Colchester time the sea stood at least as low as 112 feet below its present level. The geomorphological features of the valley are consistent with this having occurred either before or after Kirkwood time, and in either the Addo or Colchester cycles. The occurrence of a boulder-horizon at 80 to 90 feet below sea-level,

as well as at -112 feet, may indicate two distinct still-stands of the sea, perhaps separated by a period when the sea stood above its present level. The aggradation of late-Colchester time (p. 364) may be due to a rise in sea-level, following upon a fall of sea-level to below its present level in the early stages of that cycle.

Conclusion.

On the evidence of the terraces alone it is impossible to decide whether the record of sea-level changes is to be attributed to eustasy, epeirogenesis, or both. There is good reason to suppose that the terraces embrace the period of time covered by A. V. Krige's "Major" and "Minor Emergence" strandmarks, occurring at altitudes up to 100 feet above present sea-level. The Kirkwood and Harveyton terraces, and the intervening oscillation of the strandline, are probably to be correlated with "Major Emergence" strandmarks, recorded elsewhere at altitudes between about 20 and 100 feet above present sea-level. The Addo terrace may be the equivalent of the "Minor Emergence" strandmarks, at 15 to 25 feet, and the Colchester terrace may, perhaps, be correlated with the "resting stage in the final emergence" (Krige, A. V., 1927, p. 66), at 12 to 14 feet above sea-level. Most significant, however, is the postulated Harveyton oscillation of sea-level, suggesting the possibility that the "Major Emergence" strandmarks represent a distinct oscillation of sea-level, perhaps embracing the whole range of altitude from about present sea-level to 100 feet above it. This observation alone is such as to justify considerable caution before accepting the warping hypothesis that has been advanced by Krige, as an explanation of the variation in altitude displayed by the "Major Emergence" strandmarks, and by Dr. Haughton for his "Zone D" beaches (Haughton, S. H., 1931). As far as can be judged from the existing palaeontological and archaeological data, the "Major" and "Minor Emergence" strandmarks embrace the period from about the middle to the end of the Pleistocene (Cooke, H. B. S., 1940, Table, pp. 51–52), and since glacio-eustatic oscillations of sea-level almost certainly occurred in this period, we can reasonably assume they have played some part in the geomorphological evolution of the South African coastline. Unless we assume a remarkable coincidence, both in direction and time, of glacio-eustatic and epeirogenic oscillations, we should expect to find, in other parts of South Africa, evidence of oscillations of sea-level similar to that described from the Sundays River. Such oscillations are as likely to have occurred *since* the beginning of "Major Emergence" time as before.

The present investigation has contributed little information concerning past climates. The steepness of the Harveyton profile can be most readily explained as due to a drier climate than at present. Seaward tilting appears

to be ruled out by the gentle gradient of the Harveyton sub-alluvial profile. The development of the present flood-plain may be due to increased rainfall at the close of the Colchester cycle, but the phenomenon is not without alternative explanation.

Acknowledgments.

My thanks are due to Professor E. D. Mountain for his encouragement and inspiration, and for the readiness with which he has given his time to the discussion of problems raised by the investigation. To Dr. L. C. King I am grateful for his critical reading of the original manuscript. In an investigation of this kind, in which the observations often lend themselves to alternative explanations, the value of such criticism cannot be over-estimated. To my wife I cannot express adequately my appreciation for her encouragement and unfailing companionship in the field. I wish to acknowledge also the receipt of a grant from the National Research Board towards the expenses incurred in the investigation.

EXPLANATION OF PLATE.

Plate XI.

The profiles of the upper part of the diagram are those of the upper surface of the respective terraces. The diagonal crosses on the profiles of the lower part of the diagram indicate the height of points at the base of the alluvial deposits of terraces younger than the Harveyton. The localities refer to places on both sets of profiles, the present channel being the common line of reference.

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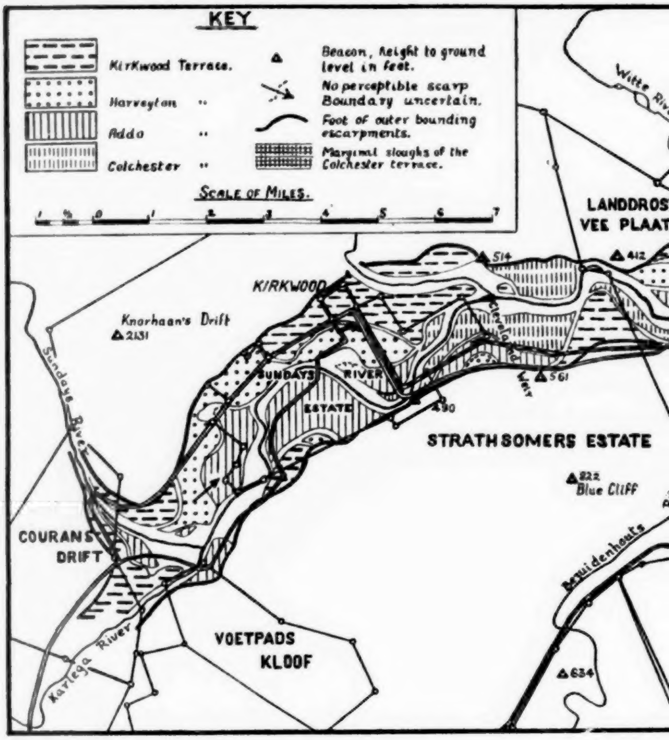
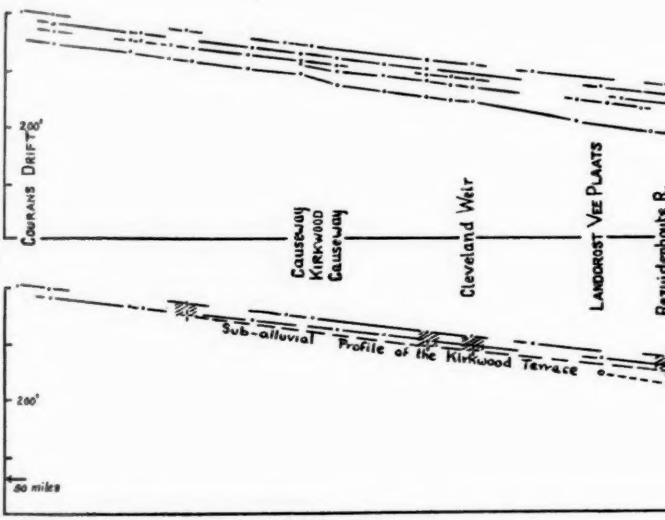
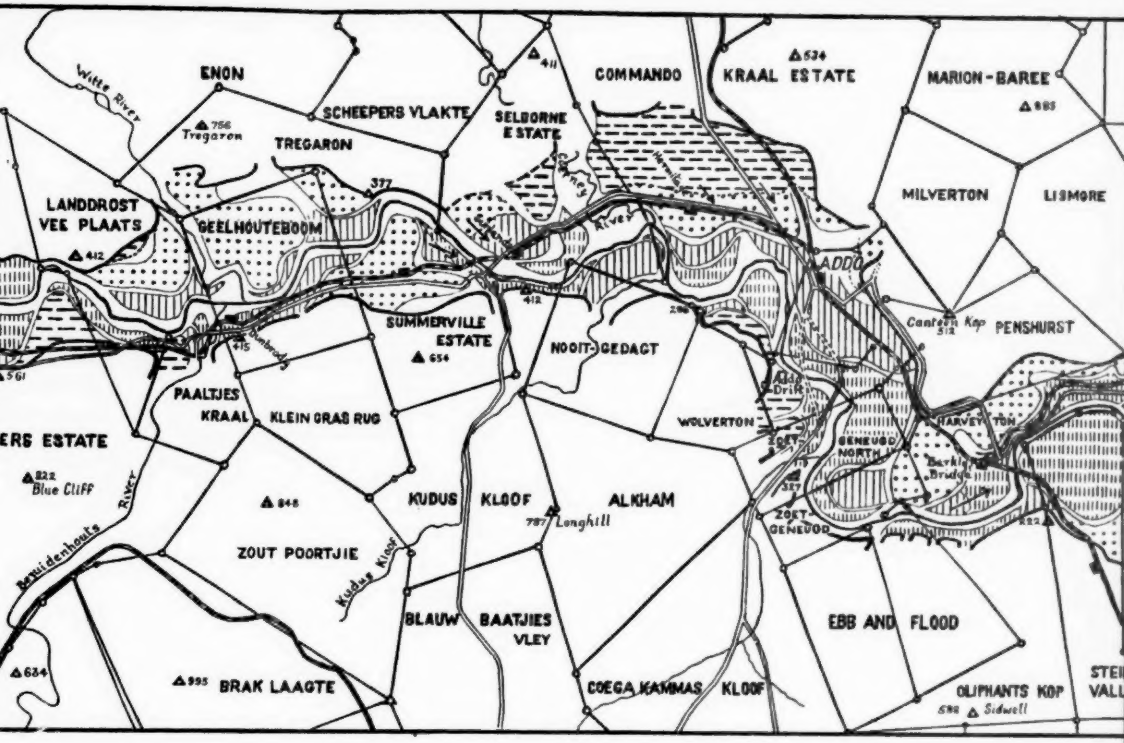


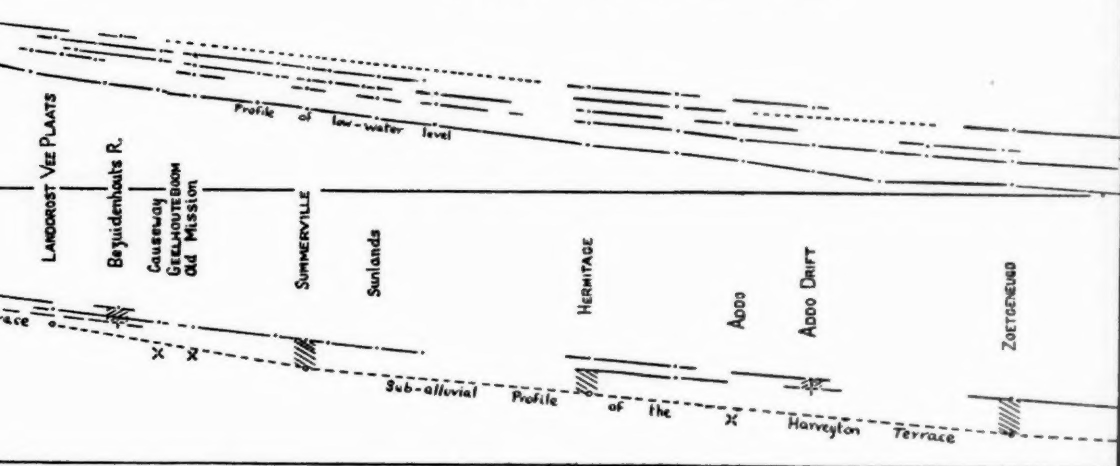


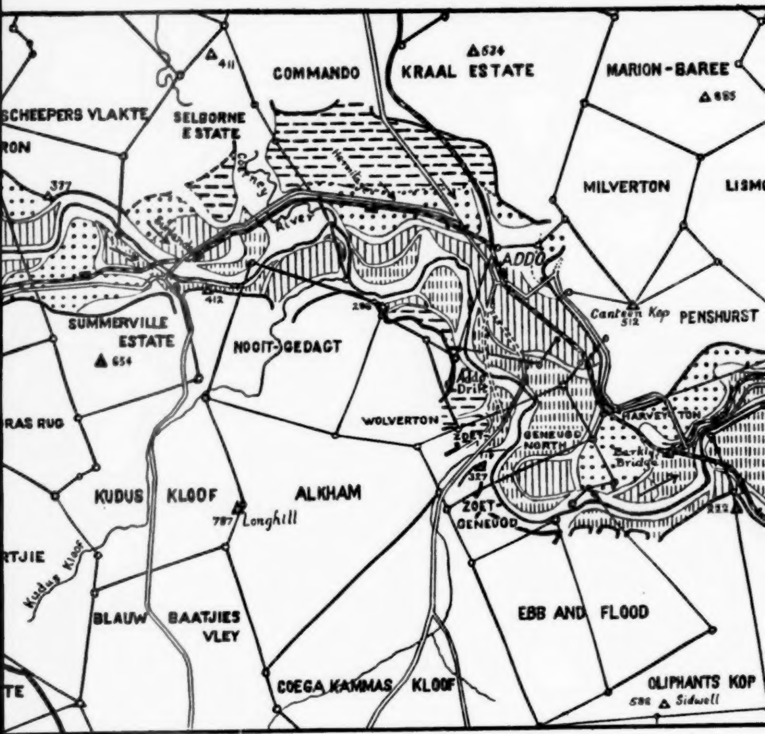
H.S. 1" = 4·05 miles. V.S. 0·68" = 200 feet. V.E. × 70.

A. Ruddock.



TERRACE LENGTH - PROFILES.





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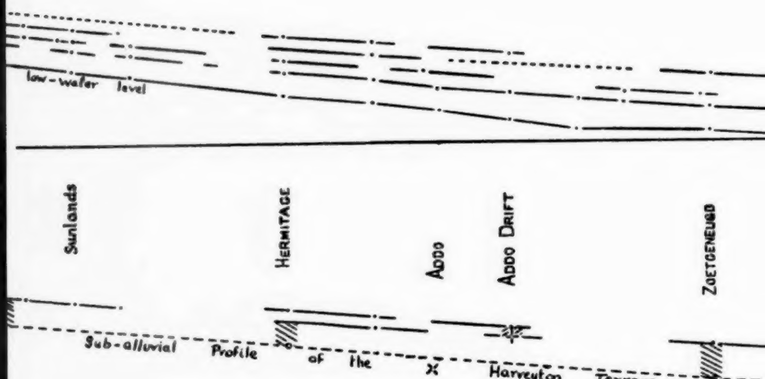
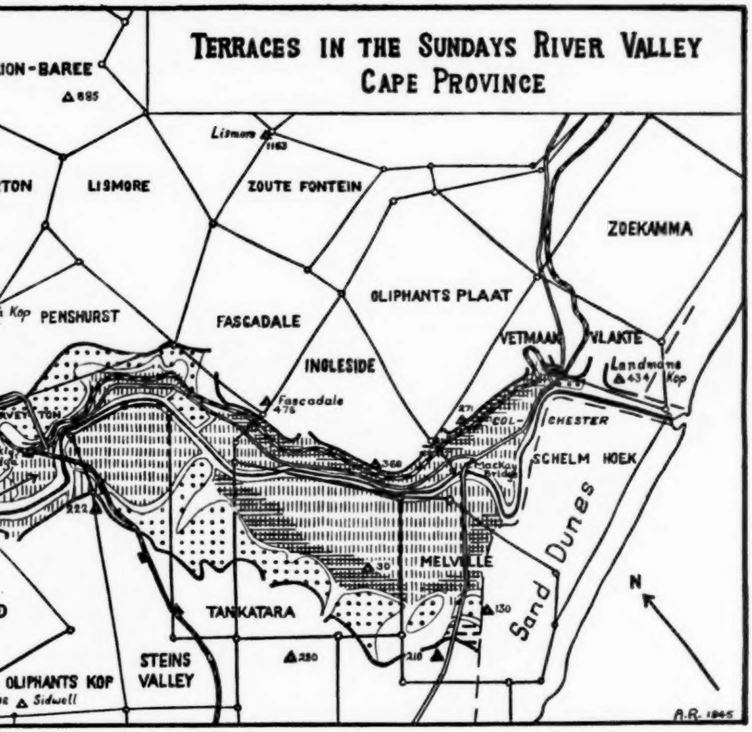
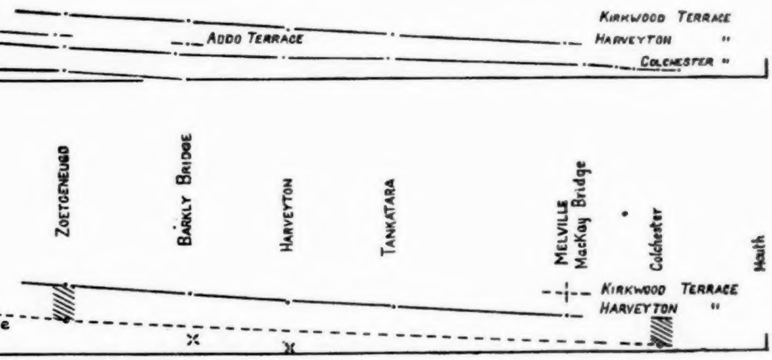



TERRACES IN THE SUNDAYS RIVER VALLEY
CAPE PROVINCE
ION-BAREE
885
Lismore
1163
TON
LISMORE
ZOUTE FONTEIN
ZOEKAMMA
OLIPHANTS PLAAT
Kop
PENSHURST
FASCADALE
INGLESIDE
VETMAAK
VLAKTE
Landmans
434
Kop
Fascadale
476
271
COL-
CHESTER
SCHELM HOEK
368
222
MELVILLE
30
130
Sand Dunes
N
TANKATARA
STEINS
VALLEY
250
OLIPHANTS KOP
Sidwell
A.R. 1945


KIRKWOOD TERRACE
ADDO TERRACE
HARVEYTON "
COLCHESTER "
ZOETGENEUGD
BARKLY BRIDGE
HARVEYTON
TANKATARA
MELVILLE
MacKay Bridge
Colchester
Mouth
KIRKWOOD TERRACE
HARVEYTON "

Neill & Co., Ltd.

SOME SOUTH AFRICAN RHODOPHYCEAE. II. *HELMINTHORA FURCELLATA* (REINBOLD APUD TYSON), COMB. NOV.

By Margaret T. Martin, Ph.D., Botanical Department, Rhodes University College, Grahamstown.

(Communicated by M. A. Pocock.)

(With Plate XII and four Text-figures.)

(Read August 15, 1945.)

Five species of *Helminthora* are listed by de Toni (1897 and 1924), of which far the best known is *H. divaricata*, recorded from the Atlantic coasts of Europe and America and from the Mediterranean. Of the remaining four species, three occur in the West Indies (Guadeloupe) and the fourth, *H. tumens* (J. G. Agardh, 1890), on the south coast of Australia (Port Phillip); up till now this latter is the only species of *Helminthora* recorded from the southern hemisphere. The present paper deals with a South African plant previously ascribed to *Nemalion*, but which must now be referred to *Helminthora*; Tyson's species *Nemalion furcellatum* now becomes *Helminthora furcellata* (Reinbold apud Tyson), comb. nov. This is the first record of *Helminthora* from South Africa, and the first southern species to be described in any detail.

The plant has only been found in a few localities on the coasts of the Cape Peninsula. It was first described by Tyson (1912) as *Nemalion furcellatum*, from specimens supposed to be sterile or male; I have since, however, been able to examine some of Tyson's specimens in the Bolus Herbarium at the University of Cape Town, and have seen female organs and cystocarps on them. According to Tyson, the plant had been seen "only at Three Anchor Bay as an annual and seldom after the New Year". Dr. G. F. Papenfuss has recorded it from Three Anchor Bay and from Sea Point, and in October 1938 he and I found a patch of these plants at "Froggy Pond", south of Simonstown in False Bay; it has also been collected by Dr. Day at Miller's Point, a few miles farther south. All the records so far are in the spring and early summer months, the latest being that of Dr. Pocock of 8th January 1943 (Three Anchor Bay)*; Dr. Pocock and I have looked for it in

* I have recently been able to visit this locality at Three Anchor Bay at an exceptionally low spring tide (6th January 1947), and found abundant and well-developed plants of *H. furcellata* uncovered for a short time by the tide. It seems that, towards the end of the summer, plants of this species disappear from the intertidal zone but still persist at a level only very rarely exposed.

vain in July, and it does not seem to appear again before September. The plants found in October are fertile, and show all stages from the early development of spermatia and carpogonia to the formation of mature cystocarps and carpospores.

The plants at Froggy Pond were growing in patches on a smooth horizontal granite boulder, a short distance above the level of low-water spring tide. The position is similar at Three Anchor Bay, but the substrate there is quartzite; owing to the rough seas on this coast the plants are washed by the waves at most low spring tides, and are probably never exposed for any long period. The thalli are attached to the rock or to the shells of limpets, are dichotomously branched, not more than two inches in length, and extremely gelatinous. The habit and situation certainly suggested *Nemalion*, but examination of the structure at once indicated that the plant should be removed from this genus and referred to *Helminthora*.

Vegetative Construction.

The plant is attached by a small basal disc, and is regularly dichotomous (text-fig. 1), its gelatinous texture and its habit being very similar to *Nemalion*. All the plants so far examined, however, are dioecious.

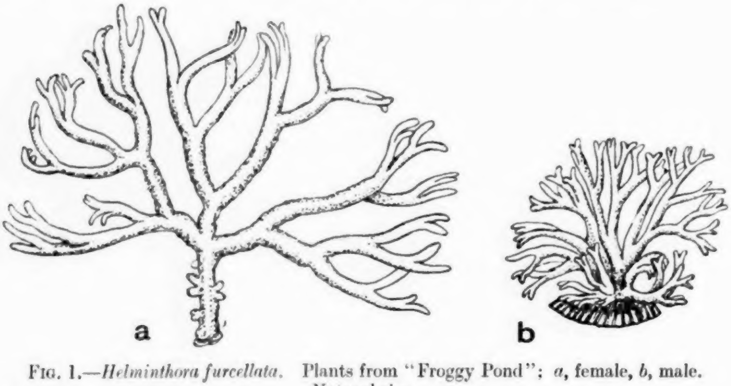


Fig. 1.—*Helminthora furcellata.* Plants from "Froggy Pond"; *a*, female, *b*, male. Natural size.

The construction of the axis is of the "fountain type", but there is a sharp differentiation into (*a*) relatively wide filaments composed of colourless cells and adhering to form a central strand or core, and (*b*) narrower filaments which arise at right angles from those of the central strand and give rise to densely branched, corymbose assimilating tufts (Pl. XII, C). This distinction is characteristic of the genus *Helminthora*, and is well seen in Thuret and Bornet's figure of *Helminthora divaricata* (1878). *H. furcellata* differs,

however, in the much longer lateral filaments, which are scantily branched below, so that the dense assimilating tuft has the appearance of being borne on a long "stalk" (Pl. XII, C); this contrasts with figures of *H. divaricata*, where the assimilating tufts are almost sessile on the central core of filaments.

An interesting feature of the axis is the presence of long narrow rhizoidal filaments which arise from the bases of the lateral branches and creep in a vertical direction amongst the much wider filaments of the central strand. Thuret and Bornet (1878) mention these for *H. divaricata* and show them to some extent in their figures; they are especially well developed in *H. furcellata*, and the filaments so formed must play an appreciable part in strengthening the main axis and in adding to its size. The corymbose tufts of assimilating filaments consist of cells each of which has a single large chromoplast, forming an inverted dome in the upper part of the cell; in the centre of each chromoplast a single pyrenoid is embedded. The cells become progressively smaller on approaching the surface; this is a feature seen also in *H. divaricata*, and contrasting with *Helminthocladia* where the terminal cell is larger than those beneath it (Hamel, 1930; Martin, 1939).

Hairs are present in the younger parts. They arise as small cells, two of which may be cut off from the upper part of a terminal assimilating cell; each of these grows out into a long unicellular and completely colourless hair (text-fig. 2, *a*, *b*). These long hairs are, however, only present in the very young parts near the growing point; they soon break off near the base, and in the older parts of the thallus hairs are scanty and always short. In *H. divaricata*, however (Thuret and Bornet's figures), long hairs appear to occur abundantly all over the mature plant.

Reproductive Organs.

The male reproductive organs are borne at the tips of the assimilating branches, as described for *H. divaricata* by Kylin (1928) and Hamel (1930), their restriction to the tips being correlated by these authors with the firm consistency of the gelatinous investment of the thallus. In *H. furcellata* three to five spermatangium mother cells are borne on the terminal cell of an assimilating filament; these are smaller than the vegetative cells, and each possesses a small plastid (text-fig. 2, *c*). Spermatangia arise laterally near the tip of each mother cell, and three or four of them are commonly produced in succession. Each is cut off by an oblique wall, and a pit connection with the mother cell can still be seen for some time. It has not been possible to recognise a plastid in the young spermatangium as described by Kylin for *H. divaricata*; when mature, the contents are colourless and a large vacuole and a nucleus in early prophase are visible. At the time of liberation about eight to ten small granules or "körnchen" can be made out

in the spermatium nucleus (text-fig. 2, *c*.) In older material the empty spermatangium walls, left by the slipping out of the spermatia, can be seen,

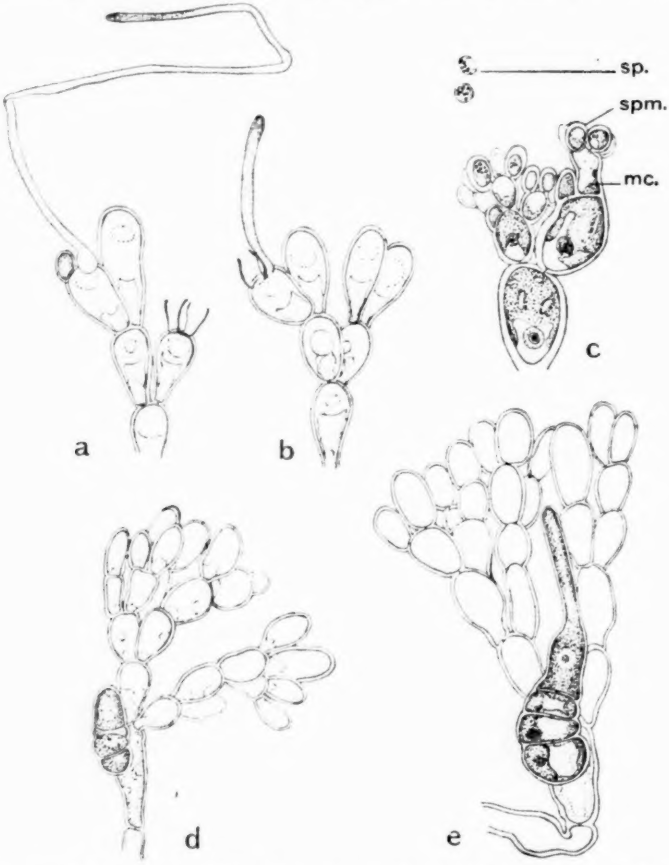


FIG. 2.—*H. furcellata*. *a*, *b*, tips of branches showing development of hairs; *c*, branch from male plant showing spermatangia and spermatia; *d*, *e*, stages in development of carpogonial branch. *mc* = spermatangium mother cell, *spm* = spermatangium, *sp* = spermatium. *c*, × 1000; *a*, *b*, *d*, *e*, × 750.

but no regeneration of secondary spermatangia through these empty sheaths has been observed.

The carpogonial branch is borne laterally on one of the assimilating filaments, the bearing cell generally occurring immediately below a dichotomy (text-fig. 2, *d*, *e*). This position differs from that in *Nemalion*, where

the carpogonial branch terminates a vegetative filament, and agrees with that in *H. divaricata*; in the latter species, however, the construction of the axis is such that the carpogonial branch and resulting cystocarp are almost sessile on the central strand, while in *H. furcellata* they are found amongst the stalked tuft of assimilating filaments (Pl. XII, A, B, C).

In structure and early post-fertilisation development the carpogonial branch agrees very closely with the descriptions and figures of Kylin (1928) and Hamel (1930) for *H. divaricata*. The very large bearing cell is present in both species, together with the four-celled branch and the peculiarly elongated carpogonium (text-figs. 2, *e* and 3, *a*). Kylin (1928) and Svedelius (1917) have both recorded a trichogyne nucleus in *H. divaricata*, cut off from that of the carpogonium at an early stage in development, but no such nucleus has yet been observed in *H. furcellata*. Text-fig. 2, *e* shows a young carpogonial branch and text-fig. 3, *a* a branch when mature. In the latter there are several spermatia attached to the trichogyne; fertilisation has, however, presumably taken place, as the trichogyne has been cut off from the carpogonium, in which a large fusion nucleus can be seen.

Development of the Cystocarp.

Post-fertilisation stages are shown in text-fig. 3, *b*, *c*, *d*, and are essentially similar to those in *H. divaricata*. Reduction division, although not observed here, presumably takes place on the first division of the fusion nucleus; text-fig. 3, *b* shows three nuclei in the carpogonium, and it is probable that, as in *Nemalion*, one of the products of the first meiotic division remains undivided. As in *Nemalion* and *Liagora*, the first wall in the fertilised carpogonium is a transverse one, and the lower cell plays no further part in development; subsequent walls in the upper cell are obliquely longitudinal (text-fig. 3, *d*) and produce a bunch of cells from which arise gonimoblast filaments bearing terminal carposporangia (text-fig. 4). Soon after fertilisation sterile filaments grow out from the two vegetative cells immediately above the bearing-cell; they are already developing while the fertilised carpogonium is still divided by only a transverse wall (text-fig. 3, *c*). These sterile filaments are of two kinds: (*a*) those which curve upwards around the fertilised carpogonium and form an "involucre" around the ripe cystocarp, and (*b*) those of rhizoidal nature which grow down the filament below the bearing-cell (*inv.* and *rh.* respectively in text-fig. 3, *c*, *d*); the latter have larger cells and are only slightly pigmented, and their investment of the filament below the carpogonial branch produces a stout "stalk" immediately beneath the cystocarp (text-fig. 4 and Pl. XII, A).

According to Hamel's account (1930, p. 73) the involucral filaments in *H. divaricata* arise from the lower cells of the carpogonial branch:

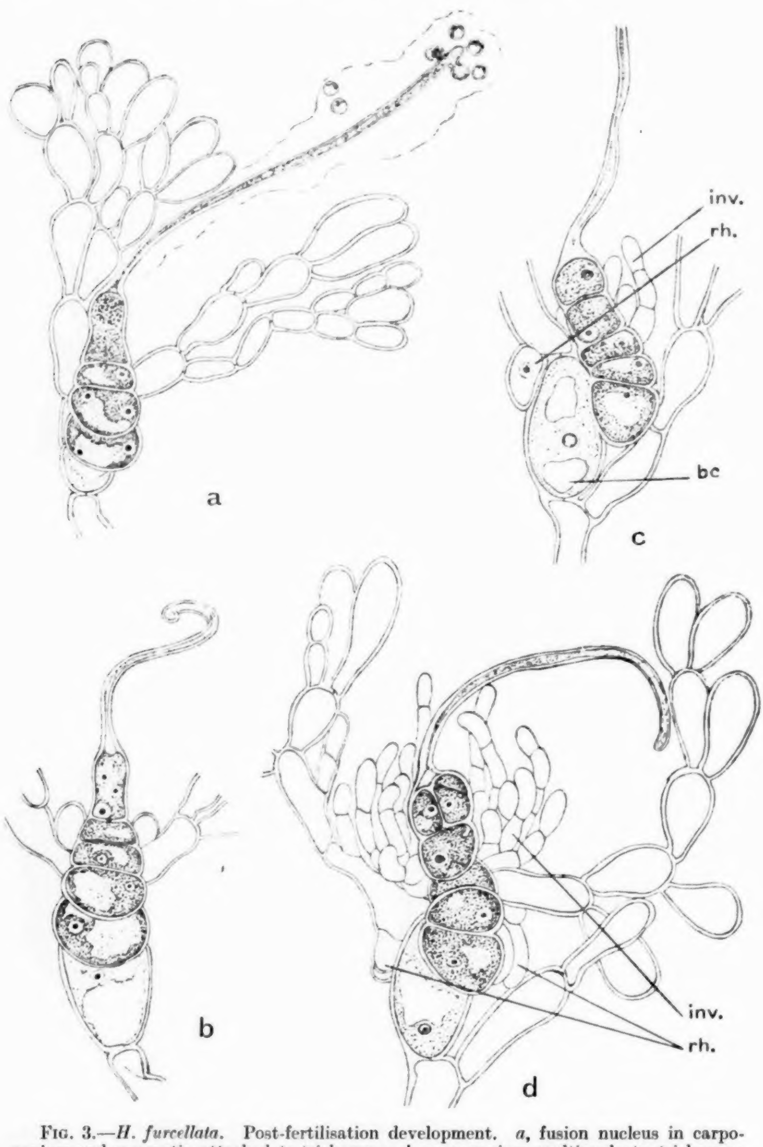


Fig. 3.—*H. furcellata.* Post-fertilisation development. *a*, fusion nucleus in carpogonium and spermatia attached to trichogyne; *b*, carpogonium multinucleate, trichogyne withering; *c*, first wall (transverse) in carpogonium, and outgrowth of sterile filaments; *d*, segmentation of upper half of carpogonium, and development of sterile involucral and rhizoidal filaments. *Inv* = involucral filaments, *rh* = rhizoidal filaments, *bc* = bearing-cell. × 750.

"Le gonimoblaste est entouré d'un involucre de filaments. . . . Ces filaments naissent des articles stériles du rameau carpogonial", and a similar statement is made by Fritsch (1945, p. 614): "The gonimoblasts become enveloped by sterile branches . . . which arise from the second and third cells of the four-celled carpogonial branch." It seems possible that these

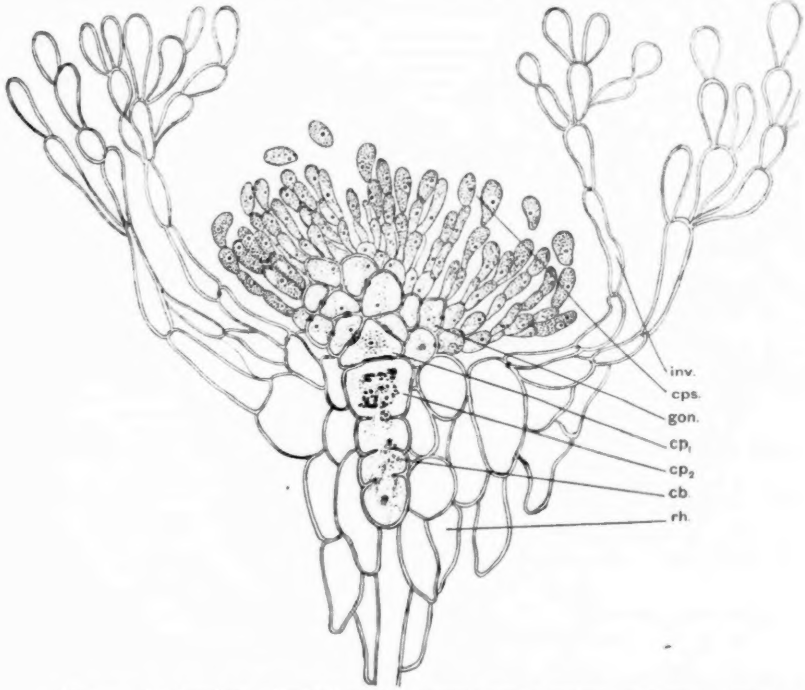


FIG. 4.—*H. furcellata.* Vertical section through nearly mature cystocarp. *Inv* = involucre, *cps* = carpospores, *gon* = gonimoblast, cp_1 and cp_2 = carpogonium, *cb* = lower cells of carpogonial branch, *rh* = rhizoidal filaments. × 400.

versions may have arisen from a misinterpretation of Kylin's statement (1928) that the covering filaments develop from the two cells lying immediately above the bearing-cell and having primary pit connections with it. Certainly in *H. furcellata* the filaments giving rise to the involucre clearly arise from the *vegetative* cells immediately above the bearing-cell, and in no case have any outgrowths been seen from the lower cells of the carpogonial branch. This agrees with Kylin's description for *H. divaricata* (1928), the origin of these sterile cells being shown in one of Kylin's figures reproduced by Fritsch (1945, fig. 230, G).

The involucre around the ripe cystocarp is especially well developed in *H. furcellata*. The cystocarps are larger than those which I have been able to examine in *H. divaricata* (in material from Roscoff, kindly sent me by Professor Kylin); many more filaments are involved in the formation of the involucre, they are more richly branched, and, while nearly colourless below, have dense plastids in the cells at their tips, a feature which gives the appearance of a well-marked "fringe" around the cystocarp (Pl. XII, A). In Pl. XII, B a "double" cystocarp is shown, formed as the result of fertilisation of two carpogonial branches in the same assimilating tuft; the two bunches of carpospores are pressed closely together and the involucre is common to the two. Text-fig. 4 shows a vertical section through a mature cystocarp. There has been a widening of the pit connections between the lower cells of the carpogonial branch, and apparently some passage of contents from one cell to the other; the cells, however, do not completely fuse together, and there is no "fusion cell" comparable to that in *Helminthocladia Papenfussii* (Martin, 1939). The involucral and rhizoidal investment can be well seen in this figure.

No monospores have been observed in *H. furcellata* such as are described by Svedelius (1917) for *H. divaricata*.

Discussion.

Helminthora furcellata, then, agrees with *H. divaricata* in the essential features of axis construction, and of the structure and development of the reproductive organs. The sharp differentiation between colourless central axis and lateral assimilating filaments, the restriction of spermatangia to the tips of the assimilating filaments, the four-celled carpogonial branch borne in a lateral position, the segmentation of the fertilised carpogonium, and the development of a compact cystocarp with sterile investing filaments are all characters of the genus *Helminthora*. In addition, *H. furcellata* is remarkably like *H. divaricata* in several small structural details, *e.g.* the much enlarged bearing-cell and the peculiarly elongated carpogonium. It differs considerably, however, in its habit; its external appearance is very different from that of *H. divaricata*, the thallus being much shorter, stouter, and regularly dichotomous. The central core is larger and the rhizoidal filaments better developed, the result being a "tougher" thallus, well suited to the violent wave action in the habitat in which it grows. The long-stalked assimilating branches which bear the cystocarps, as well as the large cystocarps with well-developed sterile investments, are all characteristic of this plant. These features are quite constant, and justify its reference to the species *Helminthora furcellata*.

My thanks are due to Dr. G. F. Papenfuss for introducing me to the material of *Helminthora furcellata*, and to Dr. M. A. Pocock for assistance with the photographs; also to both of them for permission to use their records.

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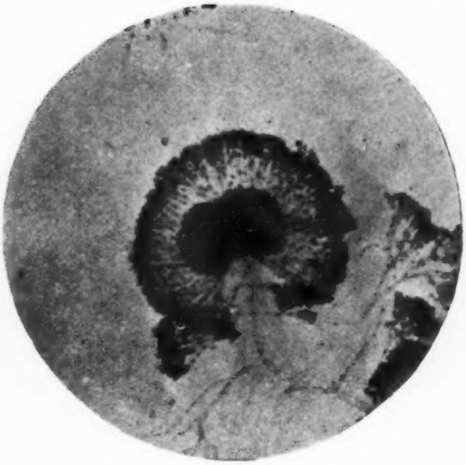
A.



B.

C.

Helminthora furcellata. A. Cystocarps in lateral and surface views, showing involucre; B. Double cystocarp (for explanation see text); C. Bart of longitudinal section through female plant showing differentiation of axis (see text). A, B, × 70; C, × about 12.

Margaret T. Martin. *Neill & Co., Ltd.*

CHARA ROTUNDA: A NEW SOUTH AFRICAN FOSSIL CHAROPHYTE.*

By Leslie E. Kent and Edith L. Stephens.

(With six Text-figures.)

(Communicated by permission of the Honourable the Minister of Mines.)

(Read September 19, 1945.)

Though parts of South Africa are rich in living Charophyta, very few fossils have been recorded. For the whole world, Groves (3) in 1933 listed 127 species as valid so far as nomenclature is concerned, but several are doubtful Charophytes owing to the imperfection of the remains. Of the 127, the only African record is *Chara Rauwi* Leriche (5) in a silicified rock occurring near the boundary of the Belgian Congo and Angola. Leriche was reluctant to date the beds, but considered that the fossil assemblage indicated either an Upper Triassic, Rhaetic, or possibly Jurassic age. Veatch (14) on the other hand, and with some justification, assigned them to the mid-Oligocene. In the same year that Groves's list was published, *Chara Saléei* Polinard (10) was described from a silcrete composed of chalcedony and opal occurring in Southern Katanga. Its age is uncertain, but Polinard considered that it is certainly not older than Jurassic and may be Tertiary or even Quaternary.

In addition to these two, there are records of seven other undetermined Charophytes from Southern Africa. Rogers and Schwarz (12) found one in a silcrete, then understood to have come from Komgha, Eastern Cape Province: this will be discussed below. Groves himself in a contribution to a paper by Newton (7) described remains of three in a chalcedonized rock from northern Matabeleland, Southern Rhodesia; but this very careful authority evidently did not consider the material sufficiently well preserved to justify either the creation of new species or their identification with existing ones, so left them as "*Chara* spp." Newton referred this chalcedonic quartzite to the Upper Cretaceous, but du Toit (2) doubted such an antiquity. Jamotte (4) reported that another Chara in a silicified sandstone from the Victoria Falls (age probably Lower Pleistocene) was "pas en assez bon état de conservation pour permettre une détermination spécifique". Mouta and O'Donnell (6) also mentioned that they found

* The botanical description of this new species is mainly the work of E. L. Stephens, and it therefore is referred to as *Chara rotunda* Stephens and Kent.

Chara fossils in silcrete capping a hill rising above the plain of Cassanje in Northern Angola. Lastly, Veatch (14) quotes Leriche as authority for a statement that Chara remains occur in silcrete on the Kundelungu Plateau, Belgian Congo. For this latter occurrence a late Pliocene age is suggested by Leriche.

These are all the records the present writers have been able to trace for the southern half of Africa. In each case the Charas are associated with shells of freshwater mollusca and the housing rocks have been silicified. Except for the Komgha specimen, none of these Charophytes appear to have particular features of interest, or to resemble the remarkable one with whose history we now deal. There is, however, a record by A. Garland of "fruits of Chara or some allied form" in a diatomaceous earth from Lake Sibayi, Zululand, collected by W. Anderson (1), while the late Dr. A. W. Rogers found fruits of a living species in a diatomaceous limestone from the farm Groenfontein 276 in the Waterberg district of the Transvaal.

In 1937, in the Standerton district of the Transvaal, Mr. F. T. Grëy, owner of the northern portion of the farm Uitkomst 251, found several small pieces of silcrete lying loose on the surface near his dam. One he gave to Mr. H. J. Hinsbeeck, who was then assistant in the laboratory of the Geological Survey. It proved to contain fossil Gasteropods and Charophyta, and in view of the apparent importance of the discovery, one of the writers arranged a visit to the locality. Despite a careful search of the surroundings no silcrete outcrop was found, but Mr. Grëy kindly presented his sole remaining specimen. A native kraal was formerly situated near the dam, and it is quite possible that the natives brought the specimens from elsewhere. It may be noted in passing that silcrete has only once been recorded in the Transvaal—on the farm Rietspruit 223 in the Heidelberg district (11), where it occurs as small lenses in a ferricrete and also directly resting on Karroo rocks. This Rietspruit silcrete is composed of "grains of quartz cemented by minutely crystalline silica" and does not resemble the Uitkomst material at all.

The two specimens together can be held within one's cupped hands. The larger, a pale lilac-pink inside, is partly covered by a shiny layer of chalcedony about 1 mm. thick. Over most of the surface this layer is a drab grey, but on one corner it changes into quite a vivid carnelian. The smaller is buff throughout and uncoated; all its surfaces are recent fractures, but it does contain a patch of sub-translucent, faintly-banded, greyish chalcedony. Both are composed of extremely fine-grained chalcedonic silica and contain numerous elongate cavities ranging up to as much as 10 mm. in length. Many of these are lined or filled with chalcedony similar in appearance to that coating the larger specimen. In some cavities this younger chalcedony is banded like an agate, in others it is mammillary. A

few might well be termed druses for they have an inner lining of minute quartz crystals; a similar lining is also seen in some of the hollow Charophyte fruits.

A little clayey matter is admixed with the chalcedony, but careful search failed to disclose the presence of any detrital quartz grains. In one thin section a few rather irregular grains were noted which showed a high relief and strong birefringence. They are extremely small and are apparently monoclinic pyroxene. A few minute flakes of sericite were also encountered. This suggests that the rock formed on dolerite which, incidentally, is very common in the Standerton district.

The original rock was almost certainly limestone which was later replaced by opaline silica. Shrinkage of this led to the opening up of cavities which were filled by younger generations of silica; but how the larger specimen came to be coated by chalcedony remains somewhat of a mystery. Superficially it resembles the highly polished stones sometimes found in springs. Several specimens of these from the Warmbaths and Riffontein thermal springs in the Transvaal were examined, but in all cases the polishing was due to abrasion and there had been no deposition of silica. Phaup (8) has recorded the presence of a smooth patina, or glaze of chalcedony, on chalcedonic implements found near the Victoria Falls. The patina ranges from pale honey to a rich deep brown in colour and possesses a splendent, vitreous lustre. It has "passed over the sharp cutting edges, rounded them and obliterated the finer chipping . . . generally, though, the whole of the surface is not patinated, and the glaze then occurs in patches with a smooth, roughly circular outline". Furthermore, the glaze penetrates tiny holes in the surface of the implements. According to Phaup the unglazed portions look as if they were the surfaces on which the implements rested, and the patina is most probably of bio-chemical origin "combined with capillary action in a climate which had a low humidity during a large part of the year". The resemblance between these patinated implements and the Uitkomst specimen is striking.

The surfaces, both natural and sawn, are dotted with shells of a small Lymnaea, and fruits and stem-fragments of a Charophyte (fig. 1). There are also casts of both shells and fruits. As the shells are completely chalcedonized, they cannot be separated from the rock, and unfortunately their apertures are in all cases in contact with it. Dr. J. V. L. Rennie, Dr. J. Hewitt, and Dr. K. H. Barnard, all of whom kindly examined the material, agree that this makes specific determination impossible, which means that the shells afford no clue to the age of the specimen.

The Charophyte fruits and stem-fragments lie in various positions, and although they cannot be dissected out, it is possible to make up from surface views and from slides the reconstructions shown in figs. 2, 3, and 6. The

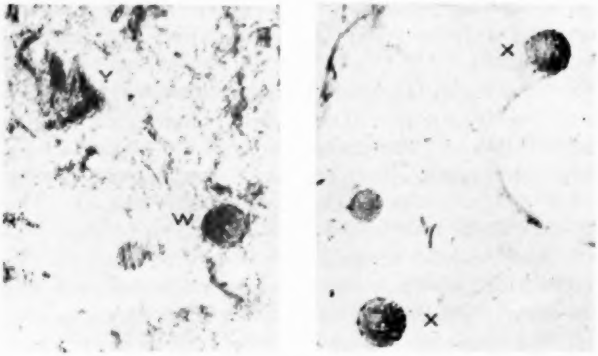


FIG. 1.—Surface views of specimen, showing fruits of *Chara rotunda*. ×7.
W. Apical view. X. Lateral views.
Y. Shrinkage cavity lined with younger chalcedony.

[*Photographs by H. J. Nel, Geological Survey.*

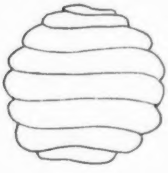


FIG. 2.

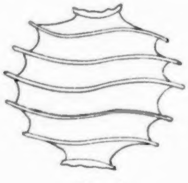


FIG. 3.

FIG. 4.

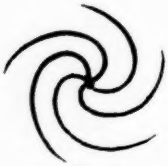


FIG. 5.

FIGS. 2–5.—Fruit of *Chara rotunda*. All ×25.
Fig. 2.—Oogonium.
Fig. 3.—Oospore.
Fig. 4.—Cast of base of fruit.
Fig. 5.—Apical view.

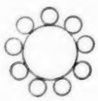


FIG. 6.—Transverse section of stem. ×25.

[*Drawings by E. L. Stephens.*]

fruit is globose and about a millimetre in diameter, which is large for a Charophyte. The shape suggests the specific name *rotunda*, and the practice usually adopted by palaeobotanists has been followed by putting it in the genus Chara. It should be noted, however, that no living Chara has a globose fruit, theirs being all more or less terete. It would perhaps be more satisfactory to place it in Tuzson's (13, p. 209) provisional genus Characeites, founded for those remains of Charophyta of which the genera cannot be determined with certainty, or in Lamarck's old genus Gyrogonites as revived by Pia (9, p. 89), but it cannot be said that either of these has yet found universal acceptance. Pia has used Gyrogonites to cover nearly all the fossils previously described under Chara, even those which obviously belong to that genus. Had he restricted it to forms with a globose fruit, like this and the original Gyrogonites (*Chara medicaginula*), it would have been a useful revival.

Owing to the nature of the rock, it was impossible to excavate so as to demonstrate the attachment of fruit to stem. But as only one type of fruit and one kind of stem are present, it is fairly legitimate to conclude that they actually belong to the same species. In the stem, the cortex (fig. 6) is of the very unusual haplostichous non-contiguous type, *i.e.* its cells are quite separate. There are usually nine of them, running parallel and independently down the outside of the large central cell. This type of cortex is found in only a very few of the living or fossil Charophyta (none African); in most corticate species the cells are in such close contact that the central cell is hidden.

The fruit of this striking plant seems nearest to that of the well-known European fossil *Chara medicaginula* Brogn. (in which Groves would include *C. Wrightii* Forbes), but the stem-remains associated with that Chara have an ordinary cortex of about 20 united cells. Mr. G. O. Allen has kindly sent us for comparison some fruits of *C. Wrightii*, dissected out from the lowest Oligocene Lower Headon Beds. The oogonia are very similar in size and appearance, but the ridges on the oospores of *C. rotunda* are wider and also thinner than those of these specimens. More detailed comparison is difficult owing to their entirely different mode of preservation. The only record of a Charophyte which may have been the same species as ours is the Komgha silcrete one mentioned above (Rogers and Schwarz, 12, p. 66). In view of the frequent mistaken references in geological literature to this silcrete specimen as from a definite "layer", and the importance evidently attached to this, it is evident that some misunderstanding exists about it. We therefore quote the original record in full:—

"A hand-specimen of a similar rock" (*i.e.* a silcrete) "from a farm about 9 miles south of Komgha village was given to the Commission by Mrs. Reany of that village. It is of particular interest because it contains the silicified

seeds of *Chara,* and the shells of a gasteropod which looks like *Limnaea.* This is the first specimen of the surface-quartzite containing clearly recognizable fossils which has come to our notice."

The Komgha locality fell well outside the area investigated by Rogers and Schwarz, and was not geologically mapped until 1939. This recent survey, however, did not reveal any occurrences of silcrete in the vicinity of Komgha.* Professor E. D. Mountain and Mr. H. B. Maufe have informed us that they too have searched unsuccessfully for silcrete in the Komgha area. As to the specimen itself, it was learnt some years later from Mrs. Reany that the stone, like ours, was only a loose one, picked up on the farm "Gold Dust" (8 miles S.W. of Komgha village) and given to her by the farmer.† As there is no silcrete on the farm, its place of ultimate origin remains as unknown as that of our specimens.

The specimen, a small one, may be somewhere in the collections of the Geological Survey, which took over the material collected by the Geological Commission, though unfortunately we have not been able to find it. But the late Dr. Rogers kindly gave us two slides that were made from it, in which are a section of a fruit that might well have been cut from *C. rotunda,* and stem sections closely resembling those of fig. 6. This is such a rare type of stem that there is a strong possibility that we are dealing with the same species. Whether it is from the same formation it is of course impossible to say, but the slides show that the specimen is of the same extremely fine-grained chalcedonic silica as ours, and like it almost certainly a silicified limestone: a type of silcrete not known to occur in the eastern Cape Province.

In the rainy season, parts of Southern Africa are dotted with pools and pans containing Charophyta and small molluscs. As the water dries the molluscs go into hibernation in the mud, among the fruits and stem remnants of the Charophyte. Perhaps our specimen had such an origin. It is hoped that the publication of this note may draw attention to the possibility that silicified pan-limestones may contain fossil Charophyta, and thus perhaps lead to the discovery of our species *in situ* and the determination of its geological horizon.

Of the two specimens on which this paper is based, one is now in the possession of the Transvaal Museum, and the other is being presented to the British Museum (Natural History), S. Kensington. A portion sawn from one of them, and Dr. Rogers' two slides, have been presented to the Geological Museum of the University of Cape Town.

* Personal communication from Mr. A. Strauss, formerly of the Geological Survey.

† For this information we are indebted to Professor E. D. Mountain and Dr. A. W. Rogers.

Chara rotunda Stephens and Kent sp. nov.

Oogonium globosum vel fere globosum, diametro 900 μ ad 1050 μ, plerumque circa 1000 μ; cellulae spirales circa 8-gyratae. Oospora plus minusve globosa; lirae circa septem, conspicuae; oospora diametro (sine liris) 750 μ ad 850 μ, lirae plerumque circa 100 μ. Caudicis cortex haplostichosus et non-contiguus, corticis cellulae plerumque novem; caudicis cellula centralis ad 350 μ in diametro, cellulae corticales in diametro pars tertia vel quarta cellulae centralis.

Oogonium spherical or almost spherical, 900 μ to 1050 μ in diameter, usually about 1000 μ, often slightly flattened at one or both poles; spiral cells showing about eight convolutions. Oospore more or less spherical, with about seven conspicuous ridges; diameter of oospore (not including ridges) 750 μ to 850 μ, ridges when not worn down usually about 100 μ. Associated stems with a haplostichous non-contiguous cortex of 8 to 10, usually 9, cells; central cell of stem 230 μ to 350 μ in diameter; cortical cells a quarter to a third of the diameter of the central cell.

Summary.

Our knowledge of South African fossil Charophyta is summarized, and a new species, *Chara rotunda* Stephens and Kent, is described from pieces of silcrete found in the Standerton district, Transvaal. A large globose fruit and haplostichous non-contiguous cortex are its distinctive characters. Its possible relationship to a Charophyte in a similar specimen from Komgha division, on the eastern seaboard of the Cape Province, is discussed. The specimens in both cases were detached ones whose geological horizon is unknown.

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NOTES ON THE DISTRIBUTION AND DENSITY OF POPULATION IN CAPE TOWN, 1936.

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(With six Text-figures.)

(Read November 15, 1944.)

The most recent data available for a study of the density of population in Cape Town are the Census Returns for 1936, when the area of the Municipality was 48,360 acres and the enumerated population 295,789. The average density was thus 6·1 persons per acre. Such a figure, however, means very little, since it covers a range extending from over 200 per acre in parts of District Six to uninhabited miles of catchment area on Table Mountain and in the Silvermine Valley. The figure for average density should be supplemented by a description of the local variations in density.

Such a description can be provided. For census purposes, Cape Town is divided into Enumerators' Areas with an average population each of about 1000. These areas are not shown separately in the official Reports; but the records relating to them have been courteously communicated to the Social Survey by the Union Office of Census and Statistics. From these records, and from information gathered in the course of a household survey in 1938, it has been possible to construct maps of the distribution and of the density of population in Cape Town which, it is believed, have a satisfactory degree of accuracy. These maps, and an account of their construction, are shown on pages 407–420. With their aid it is possible to divide the municipal area into Density Zones as follows:—

Density Zones.	Characteristic.
Non-residential Zones . .	Density less than 4 persons per acre.
Residential Zone I . .	4–16 persons per acre.
Residential Zone II . .	16–36 persons per acre.
Residential Zone III . .	36–64 persons per acre.
Residential Zone IV . .	64–100 persons per acre.
Residential Zone V . .	100–144 persons per acre.
Residential Zone VI . .	Density greater than 144 persons per acre.

The areas of the seven types of zone having been calculated (see Appendix B), a first estimate of the distribution of population among them was obtained by assuming that the mean density throughout each zone was in general equal to the mean of its limiting densities, as follows:—

Density Zones.	Acreage.	Mean Density.	Estimated Population.
Non-residential . .	34,683	say 0·2	6,937
I	8,323	10	83,230
II	3,785	26	98,410
III	1,116	50	55,800
IV	302	82	24,764
V	82	122	10,004
VI	69	say 196	13,524

The total (292,669) derived by this method showed an error of only one per cent. It was nevertheless felt desirable to reduce this error if possible, and to improve upon the assumptions that had been made as to the gradation of density within each zone. For this purpose, the population distribution map (the dot map) was superimposed upon the density map (the zone map) and a dot count carried out which yielded the following revised figures:—

Density Zones.	Population.
Non-residential . .	8,000
I	74,200
II	103,100
III	58,000
IV	26,700
V	10,500
VI	15,300

This method, which produced the expected total of 295·8 thousand, was adopted for the remaining calculations upon which this paper is based.

Of the Census population of 295,789 persons, 151,635 were returned as European, and 144,154 as Native, Asiatic, or other Non-European persons. One of the principal purposes of the present study is to compare the distribution and density of these two sub-populations. For this purpose, by the methods described in Appendix C, a map of the ethnic composition of the population of Cape Town was prepared, in which the following types of Ethnic Zone were distinguished:—

Ethnic Zone.	Characteristic.
European Residential .	Residential Zone in which more than 75 per cent. of the population was returned as European.
Mixed Residential . .	Residential Zone in which less than 75 per cent. but more than 25 per cent. of the population was returned as European.
Non-European Residential.	Residential Zone in which less than 25 per cent. of the population was returned as European.
Non-residential . .	Area with a total density of less than 4 persons per acre, irrespective of ethnic classification.

The areas and total populations of these several zones were computed by superimposition as follows:—

Ethnic Zones.	Acreage.	Total Population.
European Residential .	5,967	110,000
Mixed Residential . .	4,997	97,900
Non-European Residential .	2,713	79,900
Non-residential . . .	34,683	8,000

It follows from the above that the residents in the European Zones shared a mean density of 18·4 persons per acre, those in the Mixed Zones a density of 19·6, those in the Non-European Zones a density of 29·5, and those in the Non-residential Zones a density of 0·23. It must, however, be remembered that some Non-Europeans lived in European Zones and some Europeans in Non-European Zones. Using the method already described, the numbers of the ethnic groups within the several ethnic zones have been computed * as follows:—

* The following slightly different, but comparable, set of figures has been derived by computing the populations within Enumerators' Areas, distinguishing the latter as Predominantly European (more than 75 per cent. of the population returned as European), Mixed (25–75 per cent. European), or Predominantly Non-European (less than 25 per cent. European):—

Enumerators' Areas.	European Population.	Non-European Population.
Predominantly European . .	95,200	13,500
Mixed	49,000	48,400
Predominantly Non-European .	7,400	82,200

Ethnic Zone.	European Population.	Non-European Population.
European Residential	93,600	16,400
Mixed Residential	48,950	48,950
Non-European Residential	6,400	73,500
Non-residential	2,700	5,300

In the Reports published by the Social Survey of Cape Town it has been customary to distinguish four Survey Areas, known respectively as the Western, the Central, the Eastern, and the Southern. This geographical division, which is explained in Appendix D, is adopted in the present paper.

The Western Area.

This area, in 1936, comprised some 5720 acres. Of this, 1938 acres (or 34 per cent.) was residential in the sense defined above. The 3782 acres of non-residential land consisted almost entirely of tracts on the slopes and summit of Signal Hill and Table Mountain.

At the 1936 Census, the enumerated population of the Western Area was 52,100. Thus the mean over-all density was about 9 persons to the acre. Of the 52,100 persons, all but some 600 lived in the residential portion of the area. Thus the mean density in the residential portion of the area was about 27 persons to the acre. As Table 1A shows, however, there was considerable variation about this mean, although in no part of the area was the density of Zone V attained.

Two-thirds was non-residential. Of the residential area, more than half was accounted for by Zone II, and more than half the total population lived in this zone. Móre than a quarter of the total population, and more than half the Non-European, lived in Zones III and IV, which together amounted to less than one-eighth of the total residential area (see Table 2A).

Within the four residential zones, as density increased the proportion of Non-European population increased also, from one-eighth in Zone I to nearly three-quarters in Zone IV (see Table 3A).

Again, of the residential areas, more than 90 per cent. belonged to the European Ethnic Zone (within which, however, 12 per cent. of the population, including resident domestic servants, was Non-European). In fact, nearly half the Non-European population in the Western Area was resident in the European Ethnic Zone (see Tables 4A, 5A, 6A).

The Central Area.

This area comprised some 3930 acres. Of this, 1367 acres (or 35 per cent.) was residential in the sense in which we have defined this term. Of the 2563 acres of non-residential land, 2163 acres (or 55 per cent. of the total area) consisted of tracts on the slopes and summit of Table Mountain, while 400 acres (or 10 per cent. of the total area) comprised a coastal strip accounted for by Green Point Common, the Docks, and the Railway.

At the 1936 Census, the enumerated population of the Central Area was 58,100. Thus the mean over-all density in the Central Area was about 15 persons to the acre. Of the 58,100 persons, all but some 300 lived in the residential portion. Thus the mean density of population in the residential portion was about 42 persons to the acre. The population was, however, distributed very unequally, as Table 1B shows.

As in the Western, two-thirds of the Central Area was non-residential; but Zone II accounted for a much smaller proportion both of area and of population than in the Western Area, 83 per cent. of the population being resident in Zones III–VI, with 42 per cent. of the residential area.

As in the Western Area, the proportion of Non-European population increased with density, from 40 per cent. in Zone I to 94 per cent. in Zone VI.

In the Central Area, the three ethnic zones each amounted to one-third, more or less, of the residential area; but the Non-European Zone housed nearly two-thirds of the total population. One-third only of the European population, and one per cent. only of the Non-European, lived in the European Ethnic Zone, while 80 per cent. of the Non-European population, and 12 per cent. of the European, lived in the Non-European Zone.

The Eastern Area.

This area comprised some 5580 acres. Of this, 2152 acres, or 39 per cent., was residential. The 3428 acres of non-residential land consisted of 444 acres (8 per cent. of the whole) on the slopes and summit of Devil's Peak, 250 acres (4 per cent. of the whole) in the neighbourhood of the vacant site of the old Native location 'Ndabeni, and 2734 acres (49 per cent. of the whole) consisting of the valleys of the Salt and Black Rivers, vlei-land at Paarden Eiland and Brooklyn, and veld beyond Milnerton, surrounding the suburbs of Brooklyn and Good Hope Model Village.

At the 1936 Census, the enumerated population of the Eastern Area was 63,100. Thus the mean over-all density was about 11 persons to the acre. Of the 63,100 persons, all but some 400 lived in the residential portion. Thus the mean density of population in the residential portion was about 29 persons to the acre.

As in the Western and Central Areas, about two-thirds of the Central

Area was non-residential. Zone II is again modal both for residential area and for total population.

In the Eastern there was no such marked association between density and proportion of Non-European population as in the Western and Central Areas. This fact is commented upon in Appendix E.

In the Eastern Area the Non-European Zone was only half as large as the European or Mixed Zones and housed an even smaller proportion of the population.

The Southern Area.

This area comprised some 33,130 acres. Of this, 8220 acres, or 25 per cent., was residential in the sense in which we have defined this term. The demographic configuration differed from that of the remaining three areas in two principal respects: the absence of high "peaks" of density and the presence of numerous residential "islands" within a region characteristically non-residential.

At the 1936 Census, the enumerated population of the Southern Area was 122,500. Thus the mean over-all density was about 4 persons to the acre. Of the 122,500 persons, all but some 6700 lived in the residential portion. Thus the mean density of population in the residential portion was about 14 persons to the acre.

Three-quarters of the Southern Area was non-residential. Of the residential zones, Zone I covered much the largest area and included the largest share of each population group.

The Southern resembled the Eastern Area in that it revealed no tendency for the proportion of Non-European population to increase with increasing density (see Appendix E).

The Southern resembles the Eastern rather than the Western or Central Area in respect of the relative magnitudes of the several ethnic zones.

The Municipality.

The area of the whole Municipality was 48,360 acres and the population 295,789, divided as follows:—

Survey Area.	Acreage.	Population.
	Per cent.	Per cent.
Western	12	18
Central	8	20
Eastern	12	21
Southern	69	41
Municipality	100	100

13,677 acres belonged to the Residential Zones, with a population of 287,789, and a mean density of 21 persons per acre, as compared with a mean over-all density of 6·1 for the whole Municipality.

Of the whole area, nearly three-quarters was non-residential. Of the residential area, considerably more than half was accounted for by Zone I, though only a quarter of the population lived in this zone. The zone with the largest population was Zone II, which, with one-quarter of the residential area, housed one-third of the total population.

From Zone II onwards, increasing density was markedly associated with increasing proportion of Non-European population. But Zone I contained a slightly higher proportion of Non-Europeans than Zone II, and the Non-Residential Zone a still higher proportion (see Appendix E).

Of the residential ethnic zones, the European Zones were the largest in combined area, the Non-European the smallest. The European Zones also housed the largest share of total population and the Non-European Zones the smallest.

Of the population in the European Zones, 15 per cent. was Non-European. Of that in the Non-European Zones only 8 per cent. was European.

TABLE I.—CHARACTERISTICS OF DENSITY ZONES.

Density Zone.	Acreage.	Population.	Mean Persons per Acre.
A.—WESTERN AREA.			
Non-residential	3,782	600	0·2
I	616	7,200	11·7
II	1,094	29,900	27·3
III	158	8,800	55·7
IV	70	5,600	80·0
Whole Area	5,720	52,100	9·1
B.—CENTRAL AREA.			
Non-residential	2,563	300	0·1
I	538	4,300	8·0
II	258	6,100	23·6
III	338	15,000	44·4
IV	101	9,100	90·1
V	63	8,000	127·0
VI	69	15,300	221·7
Whole Area	3,930	58,100	14·8

TABLE I.—CHARACTERISTICS OF DENSITY ZONES—*Continued.*

Density Zone.	Acreage.	Population.	Mean Persons per Acre.
C.—EASTERN AREA.			
Non-residential	3,428	400	0·1
I	895	5,600	6·3
II	738	22,600	30·6
III	369	20,000	54·2
IV	131	12,000	91·6
V	19	2,500	131·6
Whole Area	5,580	63,100	11·3
D.—SOUTHERN AREA.			
Non-residential	24,910	6,700	0·3
I	6,274	57,100	9·1
II	1,695	44,500	26·3
III	251	14,200	56·6
Whole Area	33,130	122,500	3·7
E.—MUNICIPALITY.			
Non-residential	34,683	8,000	0·2
I	8,323	74,200	8·9
II	3,785	103,100	27·2
III	1,116	58,000	52·0
IV	302	26,700	88·4
V	82	10,500	128·0
VI	69	15,300	221·7
Municipality	48,360	295,800	6·1

TABLE II.—RELATIVE MAGNITUDES OF DENSITY ZONES.

Density Zone.	Percentage of Whole Area.	Percentage of Residential Area.	Percentage of Population.		
			European.	Non-European.	Total.
A.—WESTERN AREA.					
Non-residential	66	..	1	1	1
I	11	32	16	8	14
II	19	56	63	38	57
III	3	8	16	19	17
IV	1	4	4	34	11
Whole Area	100	100	100	100	100
B.—CENTRAL AREA.					
Non-residential	65	..	1	0	0
I	14	39	18	4	7
II	7	19	20	7	10
III	9	25	36	23	26
IV	3	7	10	18	15
V	2	5	9	15	14
VI	2	5	6	33	26
Whole Area	100	100	100	100	100
C.—EASTERN AREA.					
Non-residential	61	..	1	1	1
I	16	42	9	9	9
II	13	34	34	38	36
III	7	17	36	25	32
IV	2	6	18	20	19
V	0	1	2	6	4
Whole Area	100	100	100	100	100

TABLE II.—RELATIVE MAGNITUDES OF DENSITY ZONES—*Continued.*

Density Zone.	Percentage of Whole Area.	Percentage of Residential Area.	Percentage of Population.		
			European.	Non-European.	Total.
D.—SOUTHERN AREA.					
Non-residential .	75	. .	3	8	5
I . . .	19	76	49	44	47
II . . .	5	21	35	38	36
III . . .	1	3	13	10	12
Whole Area . .	100	100	100	100	100
E.—MUNICIPALITY.					
Non-residential .	72	. .	2	4	3
I . . .	17	61	27	23	25
II . . .	8	28	41	29	35
III . . .	2	8	22	17	20
IV . . .	1	2	6	12	9
V . . .	0·2	1	1	6	4
VI . . .	0·1	1	1	10	5
Municipality . .	100	100	100	100	100

TABLE III.—ETHNIC GROUPING WITHIN DENSITY ZONES.

Density Zone.	Estimated Distribution of Population.			Estimated Percentage Distribution of Population between Ethnic Groups.		
	European.	Non-European.	Total.	European.	Non-European.	Total.
A.—WESTERN AREA.						
Non-residential	500	100	600	83	17	100
I . .	6,300	900	7,200	88	12	100
II . .	25,500	4,400	29,900	85	15	100
III . .	6,600	2,200	8,800	75	25	100
IV . .	1,600	4,000	5,600	29	71	100
Whole Area .	40,500	11,600	52,100	78	22	100

Density Zone.	Estimated Distribution of Population.			Estimated Percentage Distribution of Population between Ethnic Groups.		
	European.	Non-European.	Total.	European.	Non-European.	Total.
B.—Central Area.						
Non-residential	200	100	300	67	33	100
I . .	2,600	1,700	4,300	60	40	100
II . .	3,000	3,100	6,100	49	51	100
III . .	5,200	9,800	15,000	35	65	100
IV . .	1,500	7,600	9,100	17	83	100
V . .	1,300	6,700	8,000	16	84	100
VI . .	900	14,400	15,300	6	94	100
Whole Area .	14,700	43,400	58,100	25	75	100
C.—Eastern Area.						
Non-residential	200	200	400	50	50	100
I . .	3,100	2,500	5,600	55	45	100
II . .	12,200	10,400	22,600	54	46	100
III . .	13,100	6,900	20,000	66	34	100
IV . .	6,600	5,400	12,000	55	45	100
V . .	800	1,700	2,500	32	68	100
Whole Area .	36,000	27,100	63,100	57	43	100
D.—Southern Area.						
Non-residential	1,800	4,900	6,700	27	73	100
I . .	29,600	27,500	57,100	52	48	100
II . .	21,000	23,500	44,500	47	53	100
III . .	8,000	6,200	14,200	56	44	100
Whole Area .	60,400	62,100	122,500	49	51	100

TABLE III.—ETHNIC GROUPING WITHIN DENSITY ZONES—*Continued.*

Density Zone.	Estimated Distribution of Population.			Estimated Percentage Distribution of Population between Ethnic Groups.		
	European.	Non-European.	Total.	European.	Non-European.	Total.
E.—MUNICIPALITY.						
Non-residential	2,700	5,300	8,000	34	66	100
I . .	41,600	32,600	74,200	56	44	100
II . .	61,700	41,400	103,100	60	40	100
III . .	32,900	25,100	58,000	57	43	100
IV . .	9,700	17,000	26,700	36	64	100
V . .	2,100	8,400	10,500	20	80	100
VI . .	900	14,400	15,300	6	94	100
Municipality .	151,600	144,200	295,800	51	49	100

TABLE IV.—CHARACTERISTICS OF ETHNIC ZONES.

Ethnic Zone.	Acreage.	Estimated Population.		
		European.	Non-European.	Total.
A.—WESTERN AREA.				
European	1,780	37,200	5,100	42,300
Mixed	88	2,400	2,500	4,900
Non-European . . .	70	400	3,900	4,300
Non-residential . . .	3,782	500	100	600
Whole Area	5,720	40,500	11,600	52,100

Ethnic Zone.	Acreage.	Estimated Population.		
		European.	Non-European.	Total.
B.—Central Area.				
European	373	4,800	600	5,400
Mixed	547	7,900	7,900	15,000
Non-European	447	1,800	34,800	36,600
Non-residential	2,563	200	100	300
Whole Area	3,930	14,700	43,400	58,100
C.—Eastern Area.				
European	802	19,400	3,000	22,400
Mixed	949	15,000	15,000	30,000
Non-European	401	1,400	8,900	10,300
Non-residential	3,428	200	200	400
Whole Area	5,580	36,000	27,100	63,100
D.—Southern Area.				
European	3,012	32,700	7,700	39,900
Mixed	3,413	23,600	23,600	47,200
Non-European	1,795	2,800	25,900	28,700
Non-residential	24,910	1,800	4,900	6,700
Whole Area	33,130	60,400	62,100	122,500
E.—Municipality.				
European	5,967	93,600	16,400	110,000
Mixed	4,997	48,900	49,000	97,900
Non-European	2,713	6,400	73,500	79,900
Non-residential	34,683	2,700	5,300	8,000
Municipality	48,360	151,600	144,200	295,800

TABLE V.—RELATIVE MAGNITUDES OF ETHNIC ZONES.

Ethnic Zone.	Percentage Distribution of Whole Area.	Percentage Distribution of Residential Area.	Percentage Distribution of Population among Ethnic Zones.		
			European.	Non-European.	Total.
A.—Western Area.					
European	31	92	92	44	81
Mixed	2	4	6	22	9
Non-European	1	4	1	34	8
Non-residential	66	..	1	1	1
Whole Area	100	100	100	100	100
B.—Central Area.					
European	10	27	32	1	9
Mixed	14	40	54	18	27
Non-European	11	33	12	80	63
Non-residential	65	..	1	0	1
Whole Area	100	100	100	100	100
C.—Eastern Area.					
European	14	37	54	11	35
Mixed	17	44	42	55	48
Non-European	7	19	4	33	16
Non-residential	61	..	1	2	1
Whole Area	100	100	100	100	100

Ethnic Zone.	Percentage Distribution of Whole Area.	Percentage Distribution of Residential Area.	Percentage Distribution of Population among Ethnic Zones.		
			European.	Non-European.	Total.
D.—SOUTHERN AREA.					
European	9	37	53	12	33
Mixed	10	42	39	38	39
Non-European	5	22	5	42	23
Non-residential	75	..	3	8	5
Whole Area	100	100	100	100	100
E.—MUNICIPALITY.					
European	12	44	62	11	37
Mixed	10	37	32	34	33
Non-European	6	20	4	51	27
Non-residential	72	..	2	4	3
Municipality	. 100	100	100	100	100

TABLE VI.—ETHNIC GROUPING WITHIN ETHNIC ZONES.

Ethnic Zone.	Estimated Percentage Ethnic Distribution of Population within each Zone.		
	European.	Non-European.	Total.
A.—WESTERN AREA.			
European	88	12	100
Mixed	49	51	100
Non-European	9	91	100
Non-residential	83	17	100
Whole Area	78	22	100

TABLE VI.—ETHNIC GROUPING WITHIN ETHNIC ZONES—*Continued.*

Ethnic Zone.	Estimated Percentage Ethnic Distribution of Population within each Zone.		
	European.	Non-European.	Total.
B.—CENTRAL AREA.			
European	89	11	100
Mixed	50	50	100
Non-European	5	95	100
Non-residential	67	33	100
Whole Area	25	75	100
C.—EASTERN AREA.			
European	87	13	100
Mixed	50	50	100
Non-European	14	86	100
Non-residential	50	50	100
Whole Area	57	43	100
D.—SOUTHERN AREA.			
European	81	19	100
Mixed	50	50	100
Non-European	10	90	100
Non-residential	27	73	100
Whole Area	49	51	100

Ethnic Zone.	Estimated Percentage Ethnic Distribution of Population within each Zone.		
	European.	Non-European.	Total.
E.—Municipality.			
European	85	15	100
Mixed	50	50	100
Non-European	8	92	100
Non-residential	34	66	100
Municipality	51	49	100

VII.

The following are among the conclusions that may be drawn from the foregoing data concerning the density and distribution of population in Cape Town at the time of the Census in 1936:—

1. The population of Cape Town was nearly 300,000, the area nearly 50,000 acres, the mean density approximately 6 persons per acre.

2. Over nearly three-quarters of the Municipality the density fell short of four persons per acre. Within this large "non-residential" area the population amounted to 3 per cent. only of the population of the Municipality.

3. Over the quarter of the Municipal area classed as residential the mean density was about 20 persons per acre.

4. A density of 200 persons per acre was reached in part of District Six where some 15,000 persons (1000 Europeans, 14,000 Non-Europeans) lived on about 70 acres.

5. The percentage distribution of total area, residential area, and total population among the four Survey Areas was as follows:—

	Total Acreage.	Residential Acreage.	Total Population.
Western Area	12	14	18
Central Area	8	10	20
Eastern Area	12	16	21
Southern Area	68	60	41
Municipality	100	100	100

6. About one-third of the total population of Cape Town lived in areas where the density was between 16 and 36 persons per acre. Somewhat less than a third lived in areas where the density was less than 16, somewhat more than a third in areas where the density was greater than 36.

7. The combined area accounted for by Zone I within each several area, and in the Municipality as a whole, was greater than that accounted for by any other Density Zone, except in the Western Area, where the zone with the greatest area was Zone II. Measured by total population, however, the largest Density Zone was Zone I in the Southern Area, Zone II in the Western and Eastern Areas and in the Municipality as a whole, and Zone VI in the Central Area.

8. Half the total population of the Municipality was European. The populations of the Eastern and Southern Areas were divided ethnically in approximately the same proportion; but in the Western three-quarters of the population was European, and in the Central three-quarters was Non-European.

9. In the Central, Eastern, and Southern Areas, the combined area accounted for by the Mixed Ethnic Zone was greater than that accounted for by either the European or the Non-European Zone. In the Western Area and in the Municipality as a whole, the European Zone accounted for the largest area. The same was true of the total populations accounted for by the Ethnic Zones, save that the zone with the largest population in the Central Area was the Non-European Zone. (But see Appendix C.)

10. Nearly two-thirds of the European population lived in predominantly European areas, and less than one-twentieth in predominantly Non-European areas. Only half of the Non-European population lived in predominantly Non-European areas, and more than one-tenth (including many domestic servants) in predominantly European areas. (But see Appendix C.)

11. Of the residential areas, those predominantly European and those of more or less equally mixed population were each about twice as extensive as those predominantly Non-European in character. Although the total European population of the Municipality was little greater than the total Non-European population, the total population of the predominantly European areas was markedly greater than that of the predominantly Non-European areas, since the number of Non-Europeans (largely domestic servants) in European areas was greater than the number of Europeans in Non-European areas. (But see Appendix C.)

APPENDIX A.

Method of Constructing Maps showing Distribution and Density of Population.

From information supplied by the Union Census Office and data collected by the Social Survey of Cape Town, the distribution of the population of Cape Town at the time of the 1936 Census was plotted on a series of maps by means of dots, one dot being placed at the approximate centre of gravity of each group of one hundred persons on a set of the official Surveyor-General's map of Cape Town and Environs (1:12,500).

Using Träger's modification of the method of Ravn, the set of dot maps was then made the basis of a set of zoned maps in which the isopleths were drawn at the limits 4, 16, 36, 64, 100, and 144 persons per acre respectively. Constructions of this kind involve an arbitrary element inasmuch as the smoothness of the isopleths depends in part upon the unit area taken as the base for the interpolations. In the construction of the Cape Town maps, an area (approximately one square inch) representing 25 acres was adopted as the base unit, so that, for instance, the statement that a certain point on the map fell within the zone "4–16 persons per acre" does not necessarily mean that it fell within an acre on which there were between 4 and 16 persons, but that it was at the centre of an area of 25 acres on which there were between 100 and 400 persons. The population of the central acre in this area might conceivably be anything from nil to 400. (An area of 25 acres is included by a circle of radius nearly 200 yards.)

At a later stage of the work, it was found that quicker and equally satisfactory results could be obtained by the use of a transparent gauge marked with a circle covering 25 acres on the scale of the map. Any particular isopleth was plotted by manoeuvring the circle in a continuous path to include as much as but no more than the particular number of dots required to define the zone intended, the line of the isopleth being recorded by a pencil through the centre of the gauge.

It had been hoped to compare the results obtained by thesemethods with certain applications of Träger's method to the population of the Peninsula published by J. H. Moolman during the progress of the present work. It appeared, however, that Dr. Moolman's maps had been constructed on a basis which did not lend itself to this comparative treatment.

For the device used for deriving statistical data from measurement of the areas bounded by isopleths, the present paper is indebted to Ernest W. Mowrer's paper.

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APPENDIX B.

Method of Computing Areas.

The areas of the several zones were computed from the original maps by the method of counting squares on a superimposed sheet of tracing-paper divided into squares representing 6·25 acres each. The general reliability of this method was attested by the closeness with which the computed acreages for the four Survey Areas agreed with the figures kindly supplied by the City Engineer of Cape Town, as follows:—

Western Area . .	computed 5,782,	official 5,720
Central Area . .	computed 4,082,	official 3,930
Eastern Area . .	computed 5,498,	official 5,580
Southern Area . .	computed 32,600,	official 33,130

In the text of the foregoing paper the computed figures have been adjusted to bring them into exact agreement with the figures supplied by the City Engineer.

APPENDIX C.

Method of Constructing Map of Ethnic Zones.

On a set of the official Surveyor-General's map of Cape Town and Environs (scale 1 : 12,500) the approximate centre of gravity of the population of each several Enumerator's Area was marked and the percentage of Europeans in the population of the area recorded. Between each such point and the neighbouring points, those distances were set off which would by simple interpolation represent a 75 per cent. and a 25 per cent. European ethnic composition. The 25 per cent. and the 75 per cent. points being joined smoothly, a series of curves were derived, dividing the population map into the Ethnic Zones described in the text above. No curves, however, were drawn in the sparsely populated Non-Residential Zone, which was regarded as a separate type of area.

It should be noted that the method employed in this case was Ravn's and not Träger's, the base for these curves being, not the unit area of 25 acres, but the Enumerator's Area of varying extent with approximately 1000 inhabitants. To have used the 25-acre unit for both types of isopleth would perhaps have been preferable. The principal effects would probably have been to modify the line of the ethnic curves and to reduce the width of the Mixed Zones in certain districts. It is doubtful if the difference in the results would have been very great. The possibility that there would have been any difference at all serves, however, as a reminder to refrain from attaching absolute significance to the dimensions of the zones.

APPENDIX D.

The Social Survey Areas.

For the purposes of the Social Survey, the fifteen Wards into which Cape Town is administratively divided have been grouped as follows:—

Western Area (Wards 1, 4, 5).
Central Area (Wards 2, 3, 6, and 7).
Eastern Area (Wards 8, 9, and 11).
Southern Area (Wards 10, 12, 13, 14, and 15).

As well as geographical compactness, each of these four areas has a sociological unity and social characteristics which distinguish it clearly from the remaining three. It is true that parts of each area are necessarily marginal, and may even appear to belong more properly to other areas: Vredehoek and the northern part of Mowbray are clear examples. But in so far as we are bound by the limits of the present Wards, it does not appear that any alternative grouping would be better than the above. In any case, the weight of the marginal districts is not great enough to invalidate comparisons between the areas.

APPENDIX E.

The Association between Density of Population and Proportion of Non-Europeans.

In the Residential Zones of the Western and Central Areas, there was a marked association between density and proportion of Non-Europeans in the population, the percentage of Non-Europeans in the several zones being as follows:—

Zone.	Western.	Central.
I . .	12	40
II . .	15	51
III . .	25	65
IV . .	71	83
V . .	..	84
VI . .	..	94

In the Eastern and Southern Areas, and in the Municipality as a whole, this association was replaced by a relationship of a different kind, the percentage of Non-Europeans in the several zones being as follows:—

Zone.	Eastern.	Southern.	Municipality.
I . .	45	48	44
II . .	46	53	40
III . .	34	44	43
IV . .	45	..	64
V . .	68	..	80
VI . .	..	..	94

There is, however, a further important difference between these two groups of areas, which may go some way towards accounting for the first difference. The bulk of the population of Cape Town (about 75 per cent.) was resident in one continuous broad belt skirting the mountain from Bantry Bay to Plumstead. In the Western Area all except 5 per cent. of the population was resident within this belt, in the Central all except 1 per cent. In the Eastern and Southern Areas, however, about one-third of the population lived outside the belt in districts separated from it by part of the Non-Residential Zone. In the Eastern there was one district of this kind at Brooklyn and another at Maitland. In the Southern Area there were such districts at Athlone, Langa Native Location, and Black River, and groups of smaller districts of this kind at Rompe Vlei, Southfield, Retreat, and Muizenberg. Within each of these districts or groups of districts considered separately, and within the several sections of the main belt, it is a general rule, subject to the exceptions mentioned below, that the higher Density Zones have a greater proportion of Non-Europeans than the lower Density Zones; but since the ethnic composition of the population varies greatly between the several districts, this rule, as has been stated in the foregoing paper, does not apply to the aggregated districts.

The exceptions just referred to are the following:—

(i) At Brooklyn, the total population of 5300 was 37 per cent. Non-European in Zone I and 27 per cent. Non-European in Zone II.

(ii) At Maitland, the total population of 16,900 was 56 per cent. Non-European in Zone I and 52 per cent. Non-European in Zone II.

(iii) The population, amounting to 40,500, of the section of the main belt falling within the Eastern Area was 45 per cent. Non-European in Zone I, 38 per cent. Non-European in Zone II, and 34 per cent. Non-European in Zone III.

(iv) The population, amounting to 75,700, of the section of the main belt falling within the Southern Area was 33 per cent. Non-European in Zone I, 44 per cent. Non-European in Zone II, and 44 per cent. Non-European in Zone III.

The relatively small population of the Brooklyn district includes that of the Good Hope Model Village in which Europeans only are permitted to live, and the population of the Maitland district includes the numerous European inmates of the Alexandra Institution. It appears that the higher proportion of Europeans in the denser sections of these two districts may

be attributed to the presence of these two restricted communities. There is no similar factor to account for the ethnic distribution of the population of the main belt in the Eastern and Southern Areas, but it may be noted that the percentages stated under (iii) and (iv) above are fully accounted for by the presence of more Europeans than the general rule would have led us to expect in Zone III in the districts of Woodstock and Observatory.

The percentages of Non-Europeans in the populations of the several districts referred to were as follows:—

District.	Zone I.	Zone II.	Zone III.	Zone IV.	Zone V.	Zone IV.
Western Area .	12	15	25	71	..	..
Central Area .	40	51	65	83	84	94
Main Belt (Eastern)	45	38	34	45	68	..
Brooklyn. .	37	27	..	..	..	..
Maitland . .	56	52	..	..	..	..
Main Belt (Southern)	33	44	44	..	..	..
Athlone . .	64	85	..	..	..	..
Langa . .	89	100	..	..	..	..
Black River .	32	50	..	..	..	..
Rompe Vlei .	90	..	..	..	..	..
Southfield .	70	..	..	..	..	..
Retreat . .	74	..	..	..	..	..
Muizenberg .	26	32	..	..	..	..

APPENDIX F.

Changes in Density since 1904.

Especially for guidance in town planning and other branches of social administration it would be desirable to maintain records of historical changes in population density and distribution. The following are the only data at present available that are at all comparable with those for 1936:—

In 1904 the City Medical Officer of Health reported the acreage of the Municipality as 5968, of which 1607 acres, or 27 per cent., were defined as "built upon" [Corporation of the City of Cape Town, Annual Report of the Medical Officer of Health for the year ended 30th June 1904]. "In estimating the acreage built upon, the boundary of a district bordering on the shore is taken from high-water mark, and a belt of 40 feet on the mountain side of the houses on the periphery of the inhabited portion of each District is included" [*ibid.*]. The population enumerated in the Municipality at the Census of 1904 was 77,668, an over-all density of 13 persons per acre and a density of 48 persons per acre in the area "built upon".

Cape Town's peripheral dwellings are now so scattered that it is no longer as easy as it apparently was forty years ago to define the edges of

a belt 40 feet wide on the mountain side of the city. We may, however, assume that the area covered by our Density Zones I–VI corresponds fairly closely to the area that would be defined as built upon if the 1904 rule could be applied. Of the area at present identifiable as corresponding to the Municipality of 1904, approximately 2300 acres fall within the several Density Zones and approximately 3700 acres outside these zones. We should probably be justified in concluding that the "residential" portion of the old Municipality increased by 35–40 per cent. during the period 1904–1936. Over the same period the population of that area increased to approximately 87,000, an over-all density of 15 per acre and of 38 per "residential" acre.

In other words, during the period 1904–1936 the over-all density within the boundaries of the old Municipality has increased by about 10 per cent. and the mean density of the "residential" area has decreased by about 20 per cent.

By 1936 the population of the extended Municipality had increased to 295,800, the area to 48,360 acres, and the total area of the Density Zones I–VI to 13,677. These figures yield an over-all density of 6 per acre and a mean density of 21 per residential acre.

In other words, during the period 1904–1936 the over-all density within the Municipality, as contemporaneously defined, decreased by about 53 per cent., while the mean density of the residential part of the Municipality, as contemporaneously defined, decreased by about 45 per cent. Or again, we may say that during this period the population increased nearly 4-fold, the total acreage about 8-fold, and the residential acreage 8- or 9-fold. The area of the Municipality and of the residential part of the Municipality had increased more than twice as fast as the population. In 1936 the average density of population throughout the Municipality was equal to the density surpassed in the old Municipality about the year 1880.

The following table indicates the densities recorded at each official Census:—

MUNICIPALITY OF CAPE TOWN.

MEAN DENSITY OF POPULATION.

Census.	Persons per Acre.	
	Within Boundaries of Contemporary Municipality.	Within Boundaries of "Old Municipality".
1865	4·8	4·8
1875	5·5	5·5
1891	8·6	8·6
1904	13·0	13·0
1911	11·6	11·6
1921	4·8	12·6
1936	6·1	14·6

APPENDIX G.

Two Measures of Mean Density of Population.

The usual way of expressing the average density of a population is to divide the total population by the total area occupied. This is in effect to adopt the geographical unit as the basis of significance, a method which is not always the most suitable from the point of view of demographic science. For demographic purposes it is often important to compare, not the properties of *areas*, but the properties of *persons*. Thus, if 99 persons each occupied an equal share in one acre of land, and an adjacent acre was occupied by one person only, the usual method of expressing the mean density would yield a figure of 50 persons per acre—a result more acceptable from the geographical than from the demographical point of view, since while the one acre with a population of (50 – 49) persons is exactly counterbalanced by the other acre with a population of (50 + 49) persons, the one human being living at a density of (50 – 49) persons per acre is greatly outweighed by the 99 persons living at a density of (50 + 49) persons per acre. An average calculated with the number of persons, instead of the number of acres, as the denominator would yield a figure of

$$\frac{99 \times 99 + 1 \times 1}{100} = 98{\cdot}02 \text{ persons per acre.}$$

This figure would probably be regarded as the more appropriate for the purposes of demographic analysis, and may be called the demotic mean density as distinguished from the figure obtained in the usual way, which may be described as the geographic mean density.

From the data used in the present paper, the demotic mean density of the ethnic groups of the population of each Survey Area and of the Municipality as a whole has been estimated as follows:—

Demotic Mean Densities of the Population.

Survey Area.	Persons per Acre.		
	Europeans.	Non-Europeans.	Total.
Western . . .	31	49	35
Central	55	121	104
Eastern	51	53	52
Southern . . .	21	20	20
Municipality . . .	34	59	46

These figures were derived by calculating the weighted mean geographic density of the several Density Zones in each Survey Area, adopting as weights the corresponding European and the Non-European populations. The figures may therefore be regarded as slight under-estimates.

APPENDIX H.

Acknowledgments.

Grateful acknowledgment is made to Mrs. Helen M. Batson for her share in the preparation of the maps; to Professor W. Talbot and Dr. T. Kelly for criticisms; to the Social Survey of Cape Town and its sponsors for permission to use data and reproduce maps.

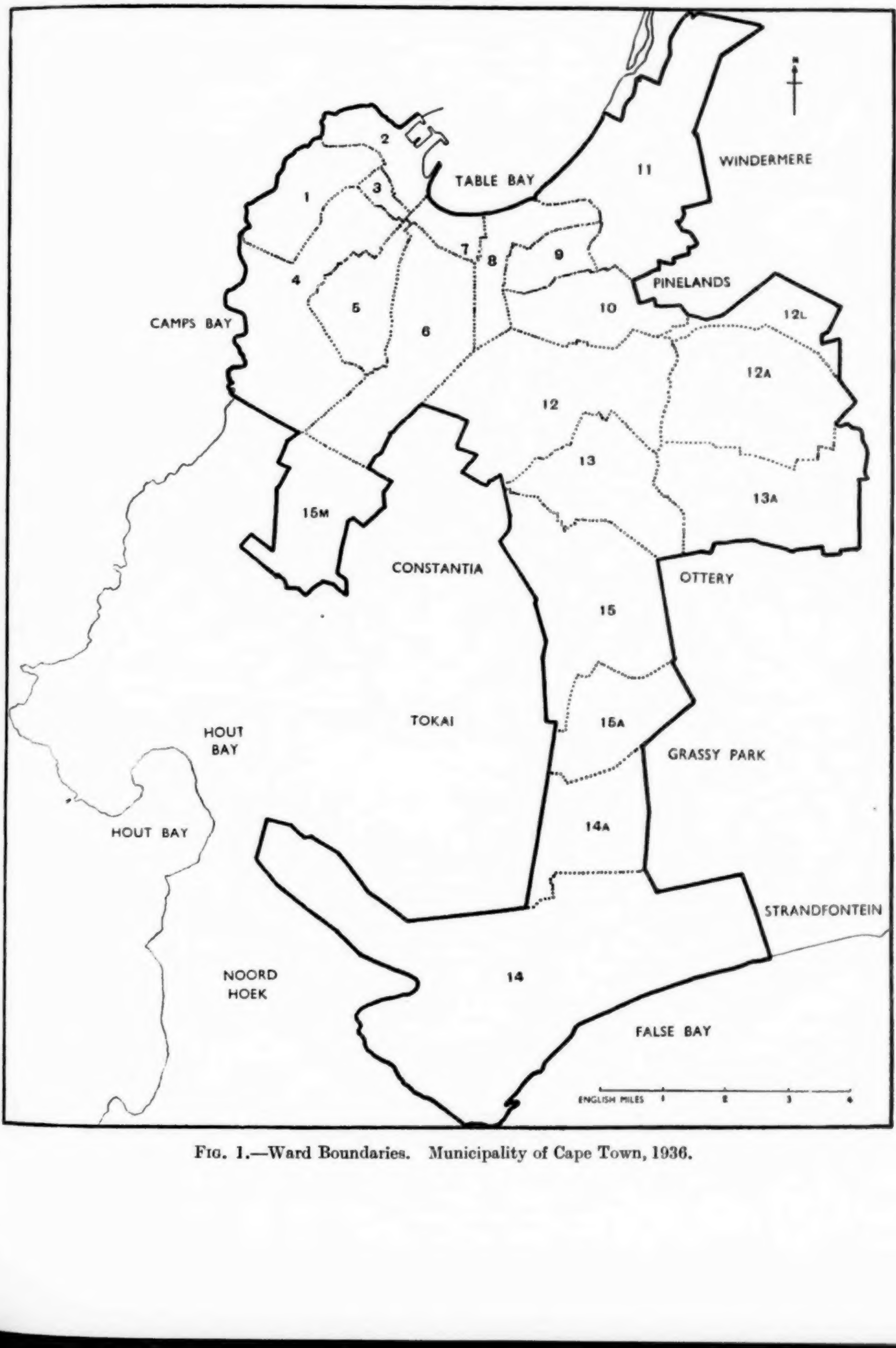

FIG. 1.—Ward Boundaries. Municipality of Cape Town, 1936.

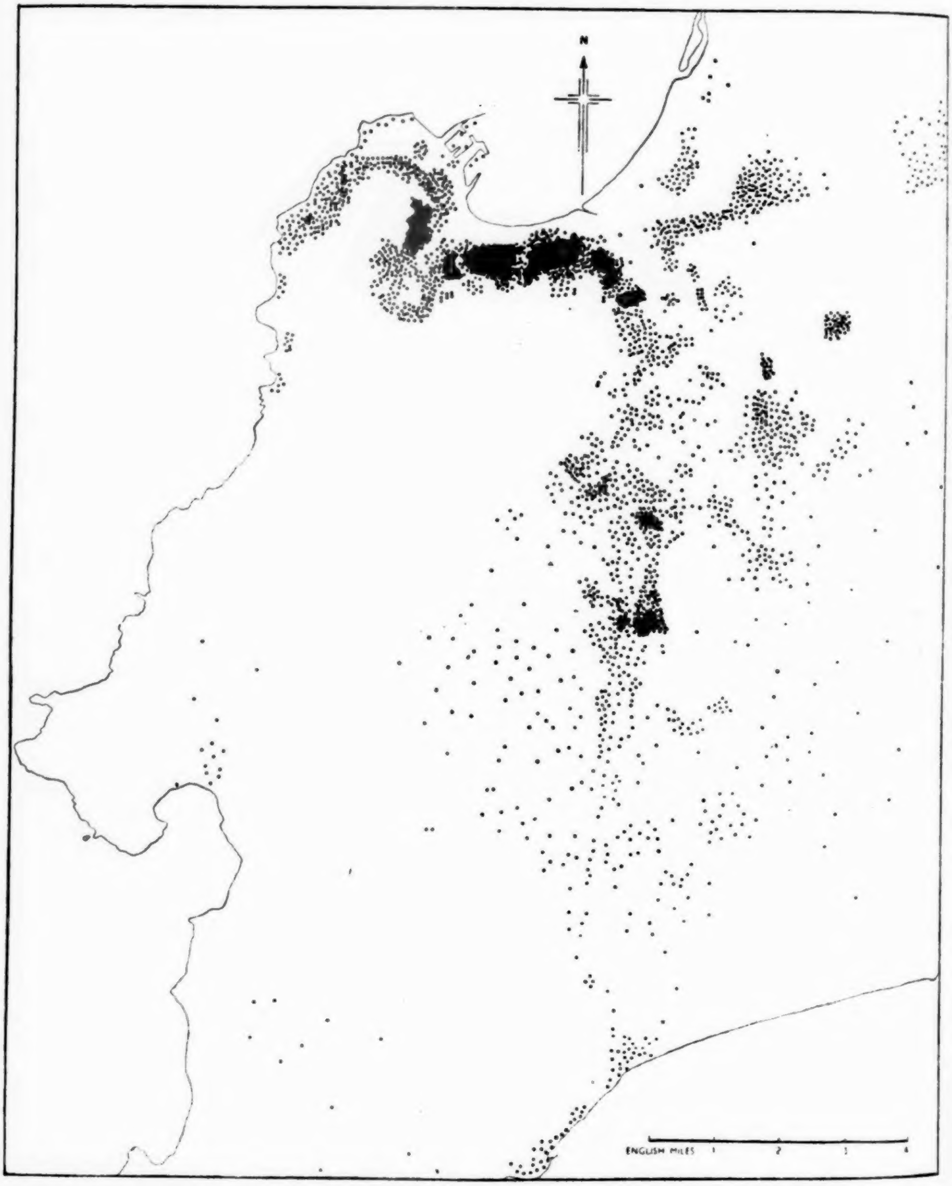

FIG. 2.—Distribution of population. Cape Town and environs, 1936. Each dot represents one hundred persons.

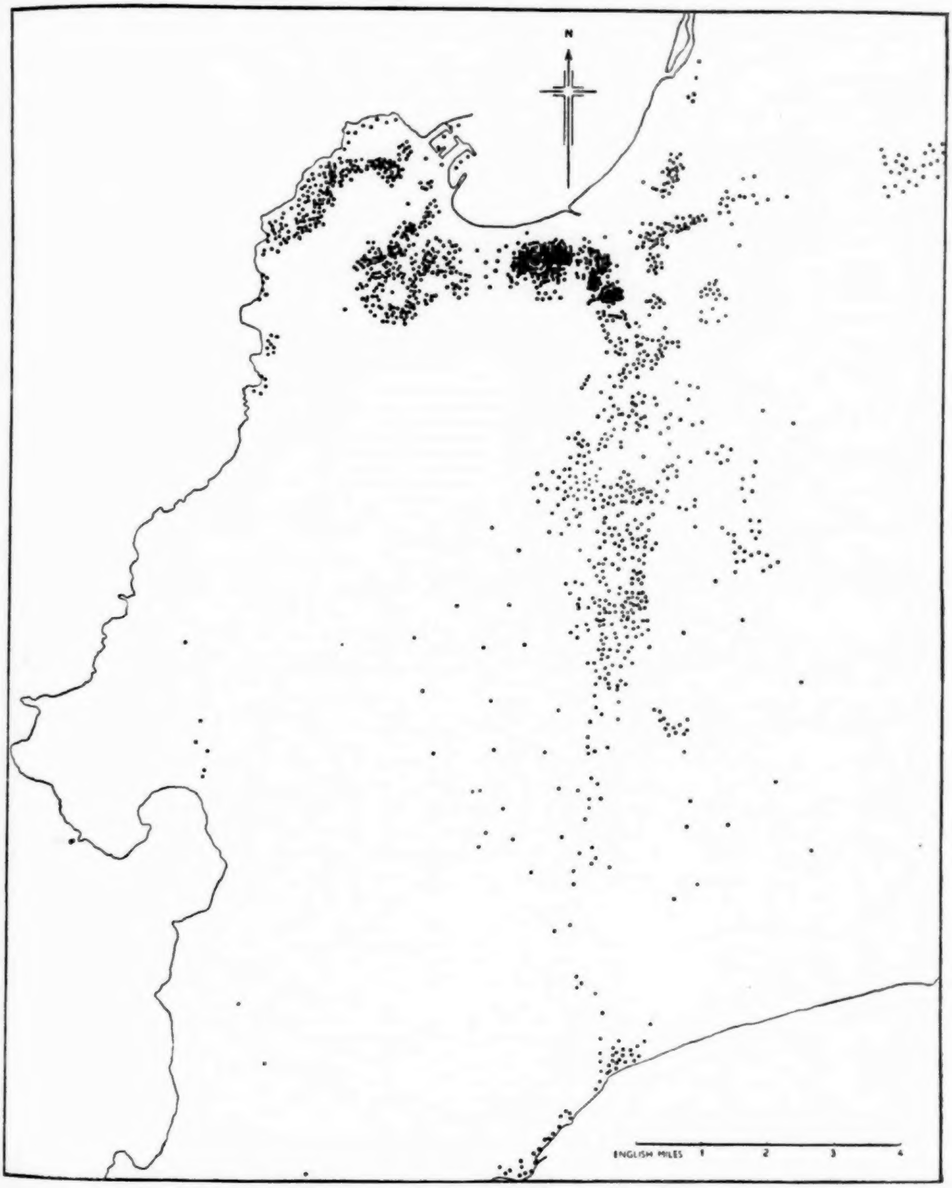

FIG. 3.—Distribution of European population. Cape Town and environs, 1936.
Each dot represents one hundred Europeans.

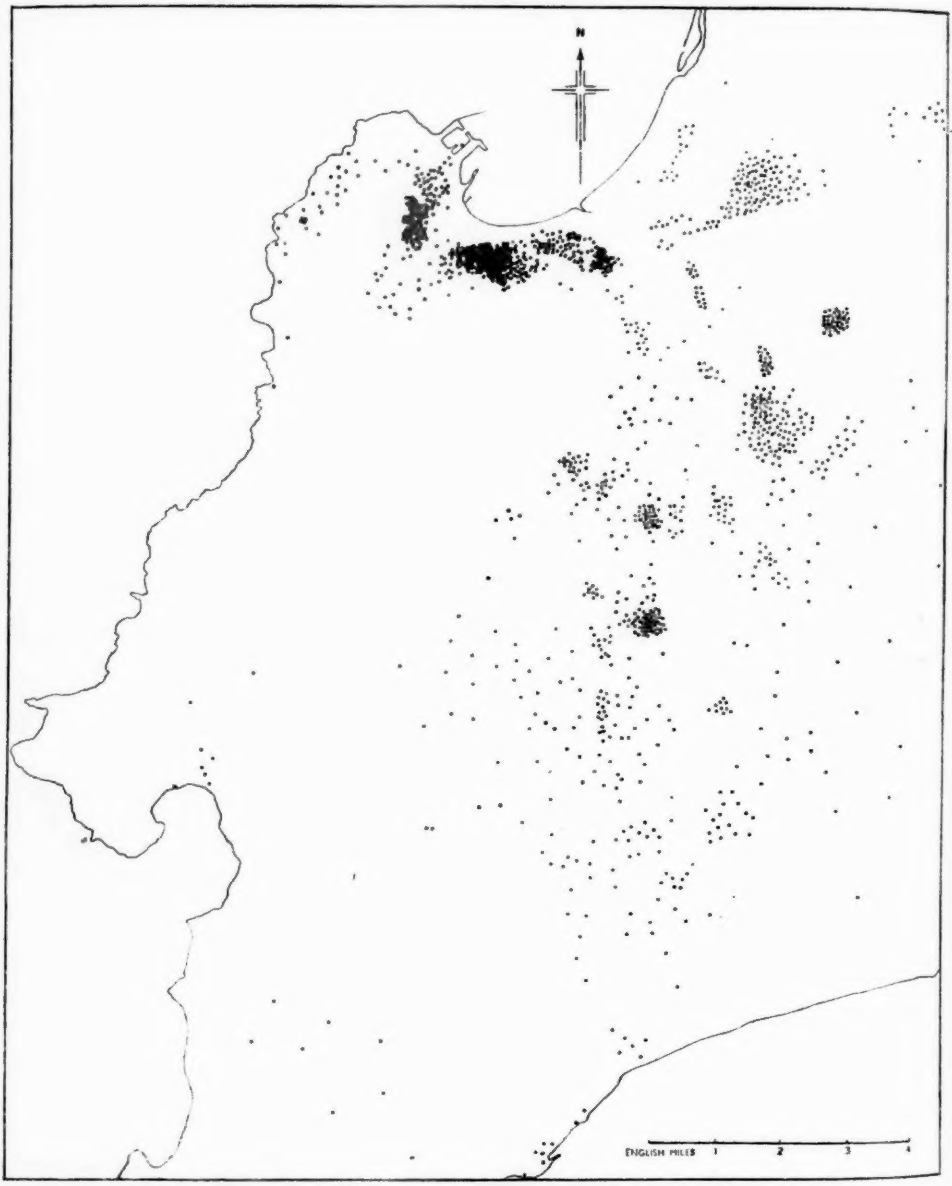

Fig. 4.—Distribution of Non-European population. Cape Town and environs, 1936. Each dot represents one hundred Non-Europeans.

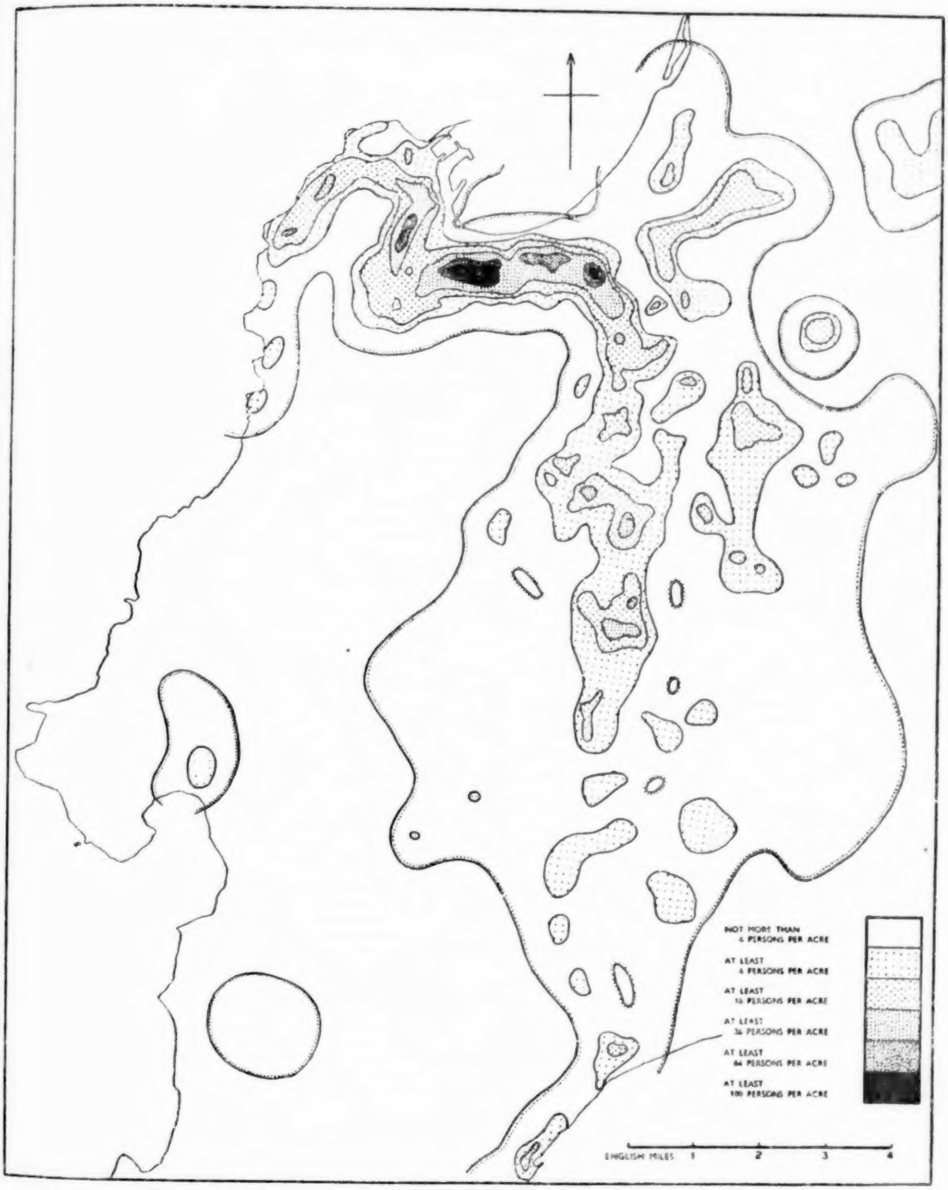

FIG. 5.—Density of population. Cape Town and environs, 1936. The outer limit approximately divides the areas with less than one person to four acres from those more densely populated.

FIG. 6.—Ethnic composition of population. Municipality of Cape Town, 1936.
The boundaries dividing the European from the Mixed Residential Zones are shown by dotted lines. Those dividing the Mixed from the Non-European Residential Zones are shown by unbroken lines.

THE APPLICATION OF PEDOLOGICAL METHODS TO THE STUDY OF SOME WEATHERED MALMESBURY ARGILLITES OF THE CAPE PENINSULA.

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(With one Text-figure.)

(Read November 21, 1945.)

ABSTRACT.

Mechanical analyses are given of two soil profiles developed from the argillaceous facies of the Malmesbury System. Data relating to chemical composition, base exchange, and optical properties of the colloidal fraction are recorded, and comparisons made with clay minerals and soil colloids from other sources. The dominant constituent of the colloids is thought to be halloysite, but no positive identification is made. The mineralogy of the fine sand fraction is also included.

CONTENTS.

INTRODUCTION.

The study of fine-grained sediments and soils has progressed rapidly since the beginning of the century. This is due mainly to the work of the soil scientist, the mineralogist, and the application of X-Ray diffraction patterns to the identification of the crystalline components of the clay fraction.

There have been two main angles of approach to this problem: that of the sedimentary petrographer, concerned principally with the identification of the various mineral constituents, and that of the pedologist, whose main centre of interest is the soil profile and the factors contributing to its development. Fundamental to the work of both groups is the study of

the clay-forming minerals, their properties and correct identification. In this sphere much remains to be done. The properties of the clay minerals have not yet been determined with any degree of certitude. Such authorities as R. E. Grim (8), S. B. Hendricks and W. H. Fry (12), and C. E. Marshall (19), give different classifications of the clay minerals. Chemical analyses of soil colloids rarely show agreement with analyses of pure clay minerals, and there is difference of opinion as to the relative value of X-ray diffraction patterns, optical and chemical data. In this connection it is interesting to note that R. H. Bray, R. E. Grim, and P. F. Kerr (4) emphasise the importance of correlating the results obtained by all three methods.

Unfortunately there is comparatively little work fulfilling these requirements. In South Africa soils and clays have been investigated chiefly by pedologists, ceramic chemists, and road engineers.

In this paper I have endeavoured to combine the techniques of the soil scientist and the mineralogist in the study of some local soils formed from the weathering of the Malmesbury formation.

Laboratory Methods.

The air-dry soil was first divided into two fractions by sieving through a 2-mm. round-hole sieve. These fractions were weighed and that > 2 mm. was recorded as a percentage weight of stones. The fine-earth, viz. < 2 mm., was further subdivided by means of a mechanical splitter, and approximately 100 gm. set aside for various determinations. All results were calculated as percentages of fine-earth dried at 105° C.

(a) *Mechanical Analysis.*

The International Soda Method (25) of dispersion was adopted with one amendment. It was found that the coarse sand fraction obtained by wet sieving invariably contained up to 10 per cent. of fine sand. The procedure adopted was therefore to place the No. 70 I.M.M. sieve containing the wet coarse sand on a cardboard base in an electric oven and dry at 105° C. The fine sand was then recovered by dry sieving and set aside for later addition to the fine sand fraction. This source of error in the standard method was discovered independently by the author, but agrees with the previous findings of B. E. Beater (2), who arrived at a similar conclusion. The pipette method of sampling the silt and clay fractions was adopted, followed by decantation to recover the fine sand. Loss by solution was determined and the results added to the figures for clay. The two sand fractions were set aside for optical examination; subsequently they were treated with 1 : 1 HCl, as recommended by D. Carroll (5), to clear

from ferruginous matter, and subdivided by bromoform separation into light and heavy crops.

(b) *Exchangeable Bases.*

25 gm. of soil were leached with 1 litre of $\frac{N}{2}$ acetic acid. The filtrate was divided into two parts for the determination of exchangeable calcium and total exchangeable bases respectively, as described by R. Williams (25). Free calcium carbonate occurs in very minor amount in the two upper horizons. This was estimated by using Collin's calcimeter. The mgm. equivalents were calculated and subtracted from the exchangeable calcium.

(c) *Clay Fraction.*

The clay for the colloidal analysis was separated by decantation after preliminary treatment with H_2O_2 and thorough dispersion. This method is described by C. H. Wright (25), following the practice of G. W. Robinson. After the bulk of the clay had been collected the remainder was set aside for optical study. The lowest particle size on which observations can be made by ordinary optical methods is ·001 mm. Use was therefore made of W. C. Krumbein's (16) data for the settling velocities of particles of ·001–·002 mm. in diameter, and appropriate corrections made for the temperature. Drops of the suspension containing these clay particles were then placed on glass slides and the water allowed to evaporate slowly. The clay minerals were then examined by the immersion method, using mixtures of methylene iodide and monobromnaphthalene, and a magnification of 840 diameters.

(d) *Single Value Determinations.*

Moisture content and loss on ignition were determined by the usual methods. The approximate pH was determined by centrifuging the aqueous suspension, adding chlorophenol red indicator and estimating the pH by comparison with the Hellige glass standards. A soil-water ratio of 1: 2·5 was used. Organic carbon was determined by A. Walkley and I. A. Black's (25) method, and the percentage organic matter estimated on the assumption that soil organic matter contains 58 per cent. carbon.

(e) *X-Ray Data.*

X-Ray powder diffraction photographs were taken by Mr. D. H. Saunder of the Physics Department, University of Cape Town. The clay fraction submitted was obtained from the C_1 horizon of the X profile and was estimated to be composed of particles having a diameter of approxi-

mately ·001–·0008 mm. This low-grade size was selected to obviate the inclusion of any unweathered material, as observations made by C. E. Marshall (19) and G. W. Robinson (20) tend to the conclusion that the coarser grades of the clay fraction, viz. ·001–·002 mm., may contain unweathered material particularly in soils developed from sedimentary rocks.

Locality and Field Description.

Two profiles were sampled, approximately 100 yards apart, from just below the De Waal Drive, Mowbray. The sub-soil clays are similar to, and continuous with, those used at W. G. Hare's brickfields.

The elevation is approximately 150 feet above sea-level. The vegetation is schlerophyllous bush (1).

Climate.—This is a winter rainfall area with an average annual precipitation of 32·04 inches, the bulk of which falls from June to September inclusive. The maximum rainfall of 7·47 inches occurs in June (6). The mean annual temperature is 63·2° F. (7). There is no snowfall and ground frosts are exceptional.

Geology.—The soils have developed from the weathering of the rocks of the Malmesbury Series, which in the peninsula consists of intercalated argillaceous and arenaceous beds. Both types have been metamorphosed by the intrusion of the Cape granite, and are now represented by the argillites and hornfelses respectively. In the sections under consideration the development of up to 100 feet of clay, underlain by weathered argillites, indicates that the source beds were of the argillaceous type. The surface horizons have been contaminated by sand produced from the disintegration of sandstone boulders which have rolled down the mountain slopes from the overlying Table Mountain Sandstone Series, the base of which stands at a height of approximately 1200 feet above sea-level and about 200 feet below Kings Battery.

Description of Profiles.—These soils are of residual origin. The A horizons appear to have been removed by erosion, and the present surface horizons show varying admixtures of sandy and gravelly material of T.M.S. origin, together with residual limonitic concretions. There is no marked zone of humus accumulation, and the low humus content appears to decrease gradually with depth. The soils are probably of the truncated podsolic type comparable to C. R. van der Merwe's (24) "gravelly sandy clay loams" developed from the Malmesbury and Bokkeveld formations farther north.

Mowbray Profile X.

Horizon B_1. Yellowish-brown structureless sandy loam with limonitic concretions, sandstone, and occasionally vein quartz pebbles. Roots are abundant. Depth 0–12 inches.

Horizon B_2. Yellow loam with granular texture and fewer concretions. Depth 12–18 inches.

Horizon C_1. Yellow to brownish clay with no stones or concretions. The clay shows fine fissuring, due partly to the penetration of larger roots and partly to shrinkage of the clay on drying out. Depth 18–36 inches.

Horizon C_2. Red clay in parts streaked with yellow or bleached white. Partially weathered slates can occasionally be seen both over and underlain by the clay. These probably represent a slightly more arenaceous facies. In this horizon the original bedding and cleavage directions of the parent rock are sometimes apparent. Depth 3–100 feet.

Mowbray Profile Z.

Horizon B_1. Yellowish gravelly sand with abundant stones and concretions. Depth 0–6 inches.

Horizon B_2. Yellowish-brown clay loam with few concretions. Depth 6–18 inches.

Horizon C_1. Reddish clay showing occasional mottling and grading into the underlying C horizon. Depth 18–24 inches.

Horizon C_2. This horizon is similar to the C_2 horizon of the X profile. Depth 2–50 feet.

Analytical Results.

(a) *Mechanical Analyses.*

The results are tabulated in the following table, and have also been plotted on the accompanying triangular diagram, after T. L. Lyon and H. O. Buckman (18).

Sample.	Horizon.	Depth.	Stones >2 mm.	Coarse Sand 2–·2 mm.	Fine Sand ·2–·02 mm.	Silt ·02–·002 mm.	Clay < ·002 mm.	Loss by Solution.	Total.
			Per cent.						
X_1	B_1	0–12 inches	4·15	42·42	19·88	18·22	19·51	0·49	100·03
X_2	B_2	12–18 ,,	3·5	11·32	38·32	35·47	14·57	0·74	99·68
X_3	C_1	18–36 ,,	0	3·77	25·74	24·46	47·24	0·23	101·21
X_4	C_2	3–100 feet	0	18·74	24·56	37·50	18·80	0·06	99·60
Z_1	B_1	0–6 inches	20·32	64·31	19·17	6·20	12·70	0·21	102·38
Z_2	B_2	6–18 ,,	4·61	16·03	33·64	23·54	25·73	0·36	98·94
Z_3	C_1	18–24 ,,	0·58	15·89	14·47	47·12	22·51	0·07	99·99
Z_4	C_2	2–50 feet	0	12·57	34·95	19·39	33·94	0·03	100·85

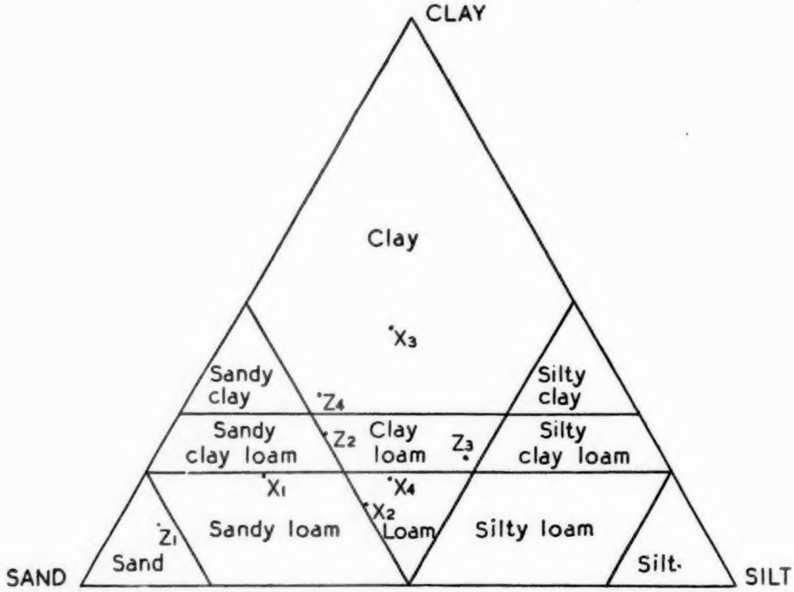

Diagram to show the Mechanical Composition of Soils

None of these analyses shows any regular variation of grade size with depth, excepting the coarse sand of the Z profile. There is, however, a marked increase in the proportion of the finer grades, viz. silt and clay, in the C_1 horizons of both profiles. It is doubtful whether this is due to mechanical illuviation alone. More probably it results from the contamination of a detrital sand in the upper zones combined with a certain amount of mechanical illuviation of the finer fractions into the C_1 horizon.

(b) *Single Value Determinations.*

Sample.	Horizon.	Depth.	Clay Content.	Organic Matter.	Ignition Loss.
X_1	B_1	0–12 inches	19·51 per cent.	1·49 per cent.	6·78 per cent.
X_2	B_2	12–18 ,,	14·57 ,,	0·92 ,,	5·99 ,,
X_3	C_1	18–36 ,,	47·24 ,,	0·93 ,,	9·74 ,,
X_4	C_2	3–100 feet	18·80 ,,	0·48 ,,	4·43 ,,
Z_1	B_1	0–6 inches	12·70 ,,	1·02 ,,	2·86 ,,
Z_2	B_2	6–18 ,,	25·73 ,,	0·56 ,,	6·22 ,,
Z_3	C_1	18–24 ,,	22·51 ,,	0·27 ,,	5·06 ,,
Z_4	C_2	2–50 feet	33·94 ,,	0·20 ,,	8·90 ,,

The clay content of the soils has been included in the above table, as the three values are interrelated. Organic matter is low, and shows a fairly steady decrease with depth. The variations in the loss on ignition are readily explained by the differences in the clay content of the soil samples.

(c) *Partial Colloidal Analyses.*

Sample.	Horizon.	Depth.	SiO_2.	Al_2O_3.	Fe_2O_3.	H_2O +.
X_1	B_1	0–12 inches	32·64	31·28	15·13	16·07
X_2	B_2	12–18 ,,	34·16	32·78	12·16	14·75
X_3	C_1	18–36 ,,	36·55	32·98	12·82	13·54
X_4	C_2	3–100 feet	38·13	26·94	17·95	14·22
Z_1	B_1	0–6 inches	28·22	30·20	17·19	17·85
Z_2	B_2	6–18 ,,	34·11	31·26	12·90	16·02
Z_3	C_1	18–24 ,,	38·38	25·54	16·13	13·52
Z_4	C_2	2–50 feet	44·98	27·82	9·36	12·65

Analyst : W. H. Herdsman.

Silica increases with depth, but iron and alumina show no regular variation. Alumina is fairly constant in the B and C_1 horizons of the X profile and in the B horizons of the Z profile; in the lower horizons it decreases.

DERIVED DATA FOR THE COLLOIDS.

(A.)

Sample.	Horizon.	Depth.	$\frac{SiO_2}{R_2O_3}$.	Molecular Ratios.		$\frac{Fe_2O_3}{Al_2O_3}$.	Molecular Equivalents.		
				$\frac{SiO_2}{Al_2O_3}$.	$\frac{SiO_2}{Fe_2O_3}$.		SiO_2.	Al_2O_3.	Fe_2O_3.
X_1	B_1	0–12 inches	1·22	1·75	4·03	0·43	·54	·31	·13
X_2	B_2	12–18 ,,	1·32	1·78	5·18	0·34	·57	·32	·11
X_3	C_1	18–36 ,,	1·42	1·90	5·54	0·34	·61	·32	·11
X_4	C_2	3–100 feet	1·50	2·42	3·94	0·61	·63	·26	·16
Z_1	B_1	0–6 inches	1·07	1·62	3·13	0·52	·47	·29	·15
Z_2	B_2	6–18 ,,	1·39	1·90	5·18	0·36	·57	·30	·11
Z_3	C_1	18–24 ,,	1·64	2·56	4·57	0·56	·64	·25	·14
Z_4	C_2	2–50 feet	2·14	2·77	9·37	0·29	·75	·27	·08

The silica : sesquioxides, and the silica : alumina ratios show regular increase with depth. These results are consistent with the supposition that the surface horizons are in all probability B horizons, and that the A horizon has been removed by erosion in this area.

(d) *Base Exchange; pH and free $CaCO_3$.*

Calcium carbonate appears to be an adventitious constituent of the soil, and the results in the last three columns of the following table have been corrected for its presence by subtracting the mgm. equivalents of exchangeable Ca and total bases. The final column shows derived data representing total exchangeable bases per 100 gm. colloid.

(B.)

Sample.	Horizon.	Depth.	pH.	Free $CaCO_3$.	Mgm. equivalents per 100 gms. Soil.		Mgm. equivalents per 100 gms. Clay.
					Ca.	Total Bases.	Total Bases.
				Per cent.			
X_1	B_1	0–12 inches	6·6	·174	4·14	5·42	27·78
X_2	B_2	12–18 ,,	6·2	·41	3·19	3·70	25·54
X_3	C_1	18–36 ,,	6·4	0	6·45	7·95	16·85
X_4	C_2	3–100 feet	6·5	0	1·99	2·72	14·46
Z_1	B_1	0–6 inches	6·5	·064	2·01	2·56	20·18
Z_2	B_2	6–18 ,,	6·2	0	6·12	6·48	25·22
Z_3	C_1	18–24 ,,	6·0	0	1·83	2·25	10·00
Z_4	C_2	2–50 feet	5·8	0	2·82	3·37	9·94

Owing to the chance presence of $CaCO_3$ in the upper two horizons, no weight can be attached to the higher values for exchangeable bases in the colloidal fraction of these samples. The exchangeable bases per cent. colloid would therefore seem to lie between approximately 10 and 20 mgm. equivalents.

(e) *X-Ray Data.*

A powder diffraction photograph was taken of the colloid X_3 by Mr. D. H. Saunder (Physics Dept., U.C.T.). Copper radiation was used. No direct correlation with published data was obtained, though the results of S. B. Hendricks and W. H. Fry (12) are included for comparison. More recent data refers to molybdenum radiation, and the lines are therefore not comparable.

The lines whose angles are recorded in the following table are all CuKα

(C.)

X_3.	Intensity.	(12) Kaolinite.	Intensity.	(12) Halloysite. Soil Colloid.	Intensity.	(12) Montmorillonite.	Intensity.
(∠±20′)		6° 11′	S.				
						8° 53′	M.W.
10° 6′	S.	10° 5′	M.W.	10° 2′		9° 51′	S.
10° 50′	S.	10° 36′	V.W.				
		11° 20′	V.W.				
12° 36′	M.	12° 22′	V.S.	12° 23′			
13° 30′	M.W.						
						14° 32′	V.W.
		15° 42′	V.W.	15° 37′	V.W.	15° 48′	V.W.
		16° 10′	V.W.	16° 8′	V.W.		
16° 54′	V.W.						
17° 36′	S.	17° 26′	S.	17° 26′	S.	17° 32′	V.S.
		17° 58′	M.S.	17° 49′	M.S.	18° 4′	V.W.
18° 45′	M.S.	19° 9′	S.	19° 16′	S.		
		19° 37′	M.	19° 40′	M.		
20° 20′	W.	20° 31′	V.W.	20° 38′	V.W.		
20° 56′	W.						
23° 2′	V.W.	22° 47′	M.W.	22° 45′	M.W.		
		23° 31′	V.W.				
		24° 40′	V.W.			24° 17′	V.W.
		25° 37′	V.W.				
27° 11′	M.			27° 20′	M.W.	27° 9′	W.
		27° 38′	W.				
28° 4′	M.			27° 58′	M.W.	27° 47′	M.W.
		28° 21′	W.				
29° 22′	W.						
30° 14′	V.W.	30° 3′	V.W.	30° 12′	M.W.		
31° 23′	V.S.	31° 10′	S.	31° 17′	V.S.	31° 3′	V.S.
		32° 7′	V.W.	32° 7′	W.		
						32° 32′	V.W.
				34° 19′	V.W.		
		35° 18′	V.W.				
		36° 9′	M.W.				
						36° 42′	M.W.
		37° 1′	M.W.	37° 5′	M.W.		
						38° 23′	M.W.
				38° 39′	M.		
		38° 45′	V.W.				
		39° 34′	V.W.				
				40° 26′			

(f) *Mineralogy.*

(1) Fine sand fraction (·2–·02 mm.)

The light crops, SG < 2·9, were composed entirely of quartz.

The percentage composition of the heavy residue, together with index figures representing the weight per cent. of heavy minerals in the undifferentiated sample, is given below. The composition was estimated from a grain count of > 500 grains, giving an accuracy of ±3 per cent. (5).

(D).

Sample.	Index Figure.	Zircon.	Opaque Fe mins.	Brown Tour-maline.	Green Tour-maline.	Blue Tour-maline.	Total Tour-maline.	Epidote.	Rutile.
X_1	0·12	32·6	44·6	14·5	6·5	0·1	17·6	..	1·7
X_2	0·15	49·4	37·3	8·6	0·5	0·7	9·8	2·8	0·7
X_3	0·13	50·0	30·0	13·0	2·5	1·0	16·5	2·5	1·0
X_4	0·14	56·3	32·9	5·8	0·7	1·1	7·6	0·5	2·7
Z_1	0·10	42·5	39·3	9·6	4·5	1·5	15·6	..	2·6
Z_2	0·05	38·2	51·6	1·6	4·1	0·8	6·5	..	3·7
Z_3	0·17	50·3	34·8	6·1	1·5	0·7	8·3	2·4	4·2
Z_4	0·29	57·2	29·4	10·0	0·4	0·3	10·7	..	2·7

Zircon crystals are mostly colourless, though all shades from grey through yellow to brown also occur. Approximately two-thirds are rounded, the remainder showing good pyramidal terminations.

Tourmaline. Two types of brown tourmaline are present.

Type (a) has the following properties :—

RIs. Z = 1·658. X = 1·634. Pleochroism. Z = Very dark brown. X = Pale bluish brown.

Type (b) has the following properties :—

RIs. Z = 1·650. X = 1·629. Pleochroism. Z = Sienna Brown. X = Light yellowish brown.

Green Tourmaline. This builds small acicular crystals averaging 0·03 mm. × ·015 mm. RIs. Z = 1·654 (green). X = 1·634 (colourless).

Blue Tourmaline generally occurs as egg-shaped grains with occasional patchy colour distribution.

RIs. Z = 1·649 (blue). X = 1·629 (colourless).

Epidote is present as irregular grains showing characteristic pleochroism and high bi-refringence.

Rutile crystals are foxy-red to bright orange with the former colour predominating.

Yellow anatase and colourless garnet (probably almandine) are very rare constituents.

No correlation by means of heavy minerals could be expected in this case. The examination of a wide range of samples taken to show both lateral and vertical distribution would be necessary.

(2) Clay fraction (< ·002 mm.).

No detailed investigation of the optical properties of the clay fraction was attempted. Two types of material appeared to be present: (*a*) colourless grains with RI. approx. 1·575. These appeared isotropic, though they may have possessed very weak bi-refringence; (*b*) colourless grains with $Z = 1{\cdot}635$ (approx.) and $X' = 1{\cdot}60$ (approx.) and showing distinct interference colours.

Discussion and Comparative Data.

From a study of the available literature the author has decided to classify the clay minerals for purposes of this discussion under three main headings, viz.:—

I. Kaolinite–Halloysite Group.
II. Montmorillonite–Beidellite–Nontronite Group.
III. Illite Group.

Chemical, optical, and base exchange data relating to these three groups will now be considered with a view to identifying the colloidal components of the two profiles described.

(a) *Chemical Data.*

The table on p. 432 lists the chemical analyses of soil colloids most closely resembling the X and Z samples, together with analyses of known clay minerals.

It will be seen that, although the samples do not correspond in chemical composition with any of the "pure" clay minerals, the analyses agree well with several soil colloids, particularly the Cecil colloid. These colloids have been variously identified as belonging to all three groups, but it is noteworthy that all except two, viz. Nos. 6 and 8, belong to the Kaolinite–Halloysite group.

(b) *Base Exchange Data.*

There is very little data on the actual base exchange data of colloids comparable to the Malmesbury clays. W. P. Kelley, A. O. Woodford, W. H. Dore, and S. M. Brown (14) give the base exchange capacities of the Cecil colloids as varying from 13·0 to 22·0 mgm. equivalents. R. E. Grim (8) assigns the following values of base exchange capacity to the clay minerals:—

Montmorillonite = 60–100 mgm. equivalents.
Illite = 20–40 mgm. equivalents.
Kaolinite = 3–15 mgm. equivalents.
Halloysite = 6–10? (possibly more).

(E.)

Table of Colloidal Analyses.

	X_1.	1.	X_2.	Z_2.	2.	X_3.	3.	X_4.	4.	Z_1.	5.	Z_3.	6.	Z_4.
SiO_2	32·64	31·84	31·16	34·11	34·80	36·55	36·49	38·13	37·02	28·22	28·17	38·38	39·54	44·98
Al_2O_3	31·28	38·28	32·78	31·26	37·61	32·98	33·57	26·94	32·42	30·20	28·18	25·54	26·77	27·82
Fe_2O_3	15·13	10·04	12·16	12·90	10·58	12·82	8·02	17·95	12·37	17·19	16·10	16·13	13·33	9·36
H_2O+	16·07	16·56	14·75	16·02	14·06	13·54	18·87	14·22	12·68	17·85	10·76	13·52	8·24	12·65
$\frac{SiO_2}{R_2O_3}$	1·22	1·20	1·32	1·39	1·33	1·42	1·60	1·50	1·55	1·07	1·24	1·64	1·89	2·14
RIs.	1·57–1·635	1·62	..	..	..	..	1·602–1·607	..	..	..	..	..	..	..
Base Exchange Capacity.	..	..	..	..	..	..	22 mgm. equivs.		..	..	..	..	..	..
Identification	..	Halloysite.		..	Halloysite.		Halloysite + Fe oxides.		Halloysite.		..	..	Montmorill.-beidellite.	

	7.	8.	9.	10. Kaolinite (Mean of 5 Analyses).	11. Halloysite.	12. Montmorillonite (Mean of 4 Analyses).	13. Beidellite.	14. Nontronite (Mean of 4 Analyses).	15. Illite (Mean of 5 Analyses).
SiO_2	44·56	44·62	44·69	44·33	44·08	49·40	47·28	40·95	48·95
Al_2O_3	29·19	23·74	27·91	38·81	39·20	19·03	20·27	10·31	25·03
Fe_2O_3	8·40	9·92	6·34	·33	·01	1·43	8·68	26·32	7·29
H_2O+	16·20	15·96	17·60	14·25	14·74	not given.	not given.	8·97	7·28
$\frac{SiO_2}{R_2O_3}$	2·19	2·53	2·38	1·89	1·89	4·10	3·11	2·15	2·83
RIs.	1·57–1·58	1·56–1·58	1·564–1·573	..	..	..	..	..	1·588–1·610
Base Exchange Capacity.	30·5 mgm. equivs. Ca.	27 mgm. equivs. Ca.	30·5 mgm. equivs.	..	..	..	..	..	20–40 mgm. equivs.
Identification	Kaolinite–Halloysite.	Illite.	Kaolinite pre-dominant.	..	..	..	..	..	..

1. Cecil, Georgia. Robinson, W. O., and Holmes, R. S. (21).
2. Cecil, De Kalb County, Ga. (No. 3888). Analyst, Glen Edgington (12).
3. Cecil, Alabama (No. 18830). Kelley, W. P., Woodford, A. O., Dore, W. H., and Brown, S. M. (14).
4. Chester, Cecil County, Md. (No. 3462). Analyst, Glen Edgington (12).
5. Chester, near Longwood, Pa. (No. 3911). Analyst, Glen Edgington (12).
6. Huntington, Md. Robinson, W. O., and Holmes, R. S. (21).
7. Redding Colloid, Calif. (No. 16304). Kelley, W. P., Dore, W. H., Woodford, A. O., and Brown, S. M. (13).
8. San Joaquin Colloid (No. 6530). Kelley, W. P., Dore, W. H., Woodford, A. O., and Brown, S. M. (13).
9. Susquehanna Colloid (No. 16312). Kelley, W. P., Dore, W. H., Woodford, A. O., and Brown, S. M. (14).
10. Belyankin, D. S., Ivanora, V. P., Beljankin, D., and Iwanowa, W. (3); and Hendricks S. B., and Fry, W. H. (12).
11. Hendricks, S. B., and Fry, W. H. (12). 12. Hendricks, S. B., and Fry, W. H. (12); and Kerr, P. F. (15).
13. Larsen, E. S., and Wherry, E. T. (17). 14. Gruner, J. W. (11). 15. Grim, R. E., Bray, R. H., and Bradley, W. F. (10).

The total exchangeable bases of the colloid fractions of the Malmesbury clays vary from approximately 10 to 20 mgm. equivalents, and would therefore seem to indicate a clay of the Kaolinite–Halloysite type, although Illite cannot definitely be ruled out.

(c) *Optical Data.*

The following refractive index values are quoted by various authorities:—

(1) *Kaolinite.*

$Z = 1{\cdot}566$.	$Y = 1{\cdot}565$.	$X = 1{\cdot}561$,[19] and [22].

(2) *Halloysite.*

$Z = 1{\cdot}581–1{\cdot}607$.	$Y = 1{\cdot}577–1{\cdot}61$[14].
	$Y = 1{\cdot}60–1{\cdot}62$[12].
	$n = 1{\cdot}553$ (isotropic)[22].
	$n = 1{\cdot}47–1{\cdot}527$ (isotropic)[19].
	$Y = 1{\cdot}498–1{\cdot}630$ (micaceous halloysite)[19].
$Z = 1{\cdot}546–1{\cdot}550$[9].	

(3) *Montmorillonite.*

$Z = 1{\cdot}532$.	$X = 1{\cdot}511$[15].
$Z = 1{\cdot}513$.	$X = 1{\cdot}492$[22].
$Y' = 1{\cdot}527$.	$X = 1{\cdot}503$[19].

(4) *Beidellite.*

$Z = 1{\cdot}549$.	$X = 1{\cdot}517$[22].

(5) *Nontronite.*

$Z = 1{\cdot}615$.	$X = 1{\cdot}580$[22].
$Z = 1{\cdot}585–1{\cdot}66$.	$X = 1{\cdot}56–1{\cdot}63$[19].

(6) *Illite.*

$Z = 1{\cdot}58$.	$X = 1{\cdot}56$[13].
$Z = 1{\cdot}565$.	$X = 1{\cdot}543$[22].
$Y' = 1{\cdot}55–1{\cdot}565$.	$X = 1{\cdot}528–1{\cdot}543$[19].
$Z = 1{\cdot}588–1{\cdot}61$[10].	
$Z = 1{\cdot}592–1{\cdot}597$[9].	

Judging from the somewhat conflicting data above, the mineral or minerals of the Malmesbury clay might be Halloysite, micaceous Halloysite, Illite or Nontronite, though, as the latter mineral is pleochroic, it would not seem to be indicated.

Conclusions.

The colloidal fractions of the Malmesbury clay from the Cape Peninsula show a marked similarity in chemical composition, optical properties, and

base exchange to the Cecil colloids of the Southern Piedmont Plateau, U.S.A., which have been identified as Halloysite together with iron oxides. Both are developed from rocks rich in biotite; the parent rocks being biotite argillite and schistose granite-gneiss respectively. The mean annual temperature of 63° F. is the same for both areas, but the Piedmont Plateau has an annual rainfall of approximately 51 inches, well distributed throughout the year, as compared with 32 inches in the Mowbray area, the bulk of which falls in the winter months. The climatic data was taken for the station of Opelika, Alabama (23). The Cecil colloids have therefore been subjected to more severe and continuous leaching. The red colour of the Malmesbury clay, and its low $SiO_2 : R_2O_3$ ratio, is probably due, like that of the Cecil, to the presence of free hydrated iron oxides.

Definite identification of the colloidal constituents is not possible with the available data, but it is probable that halloysite is the predominant constituent. The presence or absence of illite is uncertain.

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PRESIDENTIAL ADDRESS.

SOME GEOGRAPHICAL ASPECTS OF THE CAPE FLORA.

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(Read June 18, 1947.)

In choosing a subject for this address I hope that I have selected one that will be of some general interest. The subject-matter itself undoubtedly embraces some of the widest and most fundamental problems in local botany.

At the outset I want to make it clear that I conceive an address of this kind to be essentially a general presentation of a subject and, as such, freed from the necessity for detail that would be expected in a lecture or a communication.

The subject of the relationships and origin of the Cape flora is one that has occupied the attention of phytogeographers for a long time and one that has given rise to much speculation, though there is not much general agreement at present. It is, however, no part of my present purpose to enter upon any discussion or analysis of previous work most of which will be taken for granted. Nor in my treatment can anything more than a very much generalised outline be sketched in. If by so doing one can so focus attention on, and arouse interest in, some of the problems that investigation is undertaken on them, the chief object will have been attained.

It must at once be made clear that the term Cape flora is throughout restricted to that of the rather small part of the Union in the south-west which is characterised by winter rainfall. It excludes the Karroo and the regions east of Humansdorp. The terms Cape region or Cape flora area are similarly restricted. In the past there has been some confusion caused in phytogeographical writings by treating the Cape flora and that of South Africa as the same.

As so restricted the flora is a very rich one, also very distinctive. It is, indeed, so distinctive that it is possible to recognise as belonging to it plants or groups of plants which occur in stations quite outside its main area. They are chiefly on mountains along the east side of Africa, and are found as far as the Equator and in Abyssinia and Madagascar. There are

a few such stations on high ground along the west coast. It must be pointed out that these outliers of the Cape flora are floristic groups, and not usually outlying patches of the characteristic Cape vegetation.

It is, I feel, quite unnecessary for me to give you any description of the salient features of the Cape flora. It is well known and has often been described.

In any attempt to arrive at a basis for determining the relationships of a flora with that of another region it is necessary to investigate not only the flora itself and the geographical ranges of the plants composing it, but also the conditions under which it exists and the changes which these may have undergone in the past, changes either geographical or climatic. Also, of course, such evidence of the past as can be obtained from fossils is most important.

The south-western Cape has been a rather stable land surface for a period dating back to before the appearance of angiosperms. The land has undergone minor elevations and depressions, but has not been subject to major changes such as would cause a serious change in the vegetation.

From fossil evidence it is known that in pre-angiospermic times South Africa possessed a rich flora which is preserved in the Karroo rocks. This flora, conveniently referred to as the *Glossopteris flora*, has been found not only in South Africa but also in contemporaneous rocks in India, Australasia, South America and Antarctica. Further, there is such a degree of uniformity of occurrence of many of the characteristic plants in these various regions that land connections alone can explain the distribution. On the theory of continental drift a possible explanation is forthcoming. In the mesozoic epoch there was land continuity, often called Gondwanaland. This land-mass underwent disintegration, South Africa becoming separated in Cretaceous times, that is just about the time of appearance of the angiosperms. South America retained land connections with Australasia for a slightly later time. This more prolonged union gives an explanation of the greater similarities between the floras of Australasia and South America than between either of them and South Africa.

The *Glossopteris* flora which covered the once continuous Gondwanaland is now quite extinct. In Africa its end was brought about by prolonged desert conditions, the period during which the Cave Sandstone was formed. This arid period was followed by one of intense volcanic activity. These together seem to have caused complete extinction of the old flora. The question whether the present Cape flora is a direct descendant from some part of it is one that has to be considered. Some of the lines of evidence which can be used in support or against it are to be dealt with.

Plant fossils from rocks of more recent age are limited in extent in South

Africa. Those that have been studied have revealed a flora in essentials very much like that existing to-day. There are differences in distribution but not in essential features of the flora. Other data have to be relied upon for information about past climate and changes since those at the close of the *Glossopteris* period.

South Africa was not affected by the great climatic changes at the close of the Tertiary epoch that occurred in the northern hemisphere. There is evidence, however, of smaller climatic changes, especially in the direction of increased aridity. The Karroo area has certainly become much drier. Further, there is little doubt that the area occupied by the Cape flora is smaller than it was at one time. Patches of it are found on mountains surrounded by arid vegetation.

Investigations in the Little Karroo carried out by Mrs. Levyns have brought together lines of evidence that support very strongly the view that there has been a recent decrease in area caused by increasing aridity. To what extent the more distant outliers of the Cape flora can be looked upon as relics of a once continuous expanse will be noticed later on.

Within the main area of the Cape flora a noticeable feature of many of the characteristic plants is that there is a pronounced concentration of species in or about the mountain region of the south-west, with a radial diminution in numbers in all outward directions. This sort of local concentration cannot be related in any obvious way to an indication of the centre of origin of the plants concerned. It can, however, be regarded as an expression of relationship to a changing climate. The increasing aridity that has been shown to be affecting the margins of the area has almost certainly been general. The mountain mass would be that part where the effect is least, and here would retreat or persist species which are unfavourably affected by the changes. In other words, the localised concentration of species is the result of a contracting area of really favourable climate.

From the foregoing it becomes apparent that for evidence on the main theme, the relationships of the flora, investigations of the flora itself have to be relied upon. Before any explanations can be put forward, the systematic affinities and geographical ranges of the plants composing the flora have to be studied.

The Cape flora is an exceedingly rich one in species, and has a very high percentage of endemics, species, genera, and even families. Some of these endemics extend over the whole area, others are very local. Among species especially there are many with very restricted range: different though allied species often characterise areas separated geographically by short distances.

As an example of the high percentage of endemism, 100 genera were taken at random from an index list of Cape plants. Here, as in all

subsequent enumerations, alien or naturalised plants are excluded. Out of this number 42 were endemic to the Cape region; of the others, 33 were confined to South Africa and 25 more wide-spreading.

That the area of the Cape flora has been one of rather active differentiation is shown by the high percentage of local endemics, and by the distinctive species found in recently occupied land such as the Cape Flats or the coast belt north of Table Bay.

The flora has been generally regarded as an ancient one. It has all the features that are regarded as characteristic of age and long settlement, great richness in species, large numbers of endemics, and ecologically an absence of species-dominance and great local variation in the communities. The vegetation is made up of many plants with similar form and habit, that is with similar reactions to the habitat.

In many of the phytogeographical studies relating to this flora, it has been treated as a unit or at least as being geographically uniform. By this an over-simplification has been introduced, especially in comparisons made between it and other floras. It is hoped to bring forward some evidence showing that the flora and its relationships are somewhat complex, and that neither its affinities nor its past changes have been all alike.

Both floristically and ecologically the Cape flora is divisible into two readily separable parts, a mountain flora and a much more restricted forest flora. These two are so distinct that some have not regarded the forest flora as really forming part of the Cape flora at all. In what follows the mountain flora will be the part principally dealt with.

It is a generally accepted method of phytogeography for the consideration of the relationships of any flora to divide up its members in accordance with the area of distribution of the plants. Some are cosmopolitan, and these have little phytogeographical significance. Such world-wide plants are found especially among water and marsh plants, plants of the seashore, some weeds, and many Pteridiphytes. Their local occurrence seems to depend more on the existence of suitable habitats than on any other factor.

At the other end of the scale are the endemics, plants restricted to the area and sometimes very locally restricted. It is these that are especially important in giving a flora its individual character. The relationships of endemics to more widely spread plants are the most significant, but can only be determined by detailed investigation: progress is necessarily limited until such investigations are undertaken. In the most general terms endemics are of two kinds: ancient unchanging types whose existence may give a clue to past conditions, and relatively recent local modifications. The latter are the more easily associated with changes and movements in a flora.

Between these two extremes there are the greatest numbers of plants—

those with ranges relatively restricted but extending beyond the immediate boundaries. The extent of these ranges and the relationship of the plants with endemics provide one of the main lines of inquiry for elucidation of relations of the flora.

As soon as the attempt is made to apply criteria of this kind to the Cape flora it becomes apparent that it is phytogeographically complex. At the present time there are so many gaps in knowledge of the real extent of range of the plants, and still more of their real affinities, that any analysis attempted can only be on broad lines, and even so must be one open to modification as data are accumulated. The analysis that is attempted here is a very much generalised one.

Analyses of various kinds have been carried out previously. The most complete was that of Marloth. In its general outlines it is not unlike the scheme that is adopted, but contained many details that are now omitted. Recently Weimarck has elaborated a scheme based upon a study of certain plants of restricted range, but it is one much too detailed for present purposes and is one that does not cover many of the more widely dispersed plants.

To illustrate the simple analysis that is adopted, a single family, Umbelliferae, is selected. This is a family with wide range, very distinctive characters, and not represented in the flora by an excessive number of genera. Excluding non-indigenous genera, and a few that are confined to the extreme margins of the area of the Cape flora and that clearly belong to other floras, there are 25 genera. Of these, two, *Hydrocotyle* and *Seseli*, are practically cosmopolitan. Nine are endemic: *Arctopus*, *Chamarea*, *Choritaenia*, *Glia*, *Hermas*, *Lichtensteinia*, *Polemannia*, *Rhyticarpus* and *Thunbergiella*. Five genera, *Bupleurum*, *Conium*, *Cnidium*, *Sanicula* and *Torilis*, are represented here by single species but have their main distribution area in the northern hemisphere. These genera in the Cape flora are at the extreme limit of their range and can be grouped as a northern component. Five genera have ranges extending beyond the limits of the Cape flora in Africa, some throughout Africa, and have the majority of their species outside the Cape area. Of these, *Sium* and *Pimpinella* have the main range in the warmer parts, with extensions to both south and north temperate zones. *Peucedanum* extends throughout Africa and into the north temperate zone. It is a large genus divisible into sections, of which those present in the Cape flora are more nearly related to those in the adjacent parts of Africa than to those in the north temperate zone. *Capnophyllum* and *Pituranthus* are more restricted, but both extend through Central to North Africa. These genera may be grouped together as an African component. To this may be added *Sonderina*, which though limited to South Africa (Cape–Natal) is very closely related to the North African genus *Tragiopsis*.

The distribution of the remaining genera is different. *Centella* has most of its species confined to the Cape flora but a few extending to the tropics; one species occurs in Australia. *Annesorrhiza* is confined to Southern Africa and extends from the Cape region to the Transvaal and Angola. Both are essentially southern and may be grouped in an austral component. With them may be placed *Apium*, which though a world-wide genus is represented here by only two indigenous species, one a water plant, the other also found in New Zealand and South America. Among the endemics, *Hermas* which belongs to a tribe all the members of which are confined to the south temperate zone, and *Glia* which has often been united with *Annesorrhiza*, also clearly belong to this austral component.

To sum up, of the 25 genera of Umbelliferae, 2 are cosmopolitan, 5 northern, 6 African, 5 austral and 7 endemic. Even if all these endemics are added to the austral component, it appears that about half the genera have phytogeographic affinity with the north.

These components recognisable in this single family can be applied to the flora as a whole. To carry out this fully is obviously far beyond the scope of this address; it would require volumes. The most that will be attempted is to give the barest outlines of such an analysis and in it to deal only with genera or larger groups. Even such an outline may assist in the tackling of some of the wider questions that arise.

In any analysis it is obvious that the different components are not sharply separated. Without detailed studies of distribution areas and taxonomic relations it is often not possible to group plants with any degree of certainty. The African and northern components are very closely related, and probably the latter should be looked upon as only an extreme case of the former. Whether plants which occur in the Cape flora and in the outliers in Central Africa should be placed in the austral or the African components can usually only be determined by investigation of their systematic relations.

In grouping the endemics no finality is possible with most until their real affinities have been investigated. In the outline analysis that follows allowance must be made for these difficulties and imperfections.

Austral Component.

This is made up of those plants with a range confined to or mainly in the south temperate zone. It includes most of the plants which occur also in other southern lands. Many of these plants extend to the tropics, but they have their main area of distribution in the south, or are most nearly related to or derived from such plants.

Among families in this component are Xyridaceae, Restionaceae,

Haemodoraceae, Proteaceae, Hydnoraceae and Myoporaceae, also in the forest flora Podocarpaceae, Cunoniaceae and Pittosporaceae. Families very largely southern in range but less completely so are Santalaceae, Aizoaceae, and the sub-family Leptospermoideae of Myrtaceae. The endemic families Bruniaceae and Grubbiaceae, and probably also Penaeaceae and Geissolomataceae, also belong here.

The distribution in southern lands of these families is given in the following table:—

TABLE I.

No. of Genera.

	Total.	Cape.	Australia.	S. America.	
Xridaceae . .	2	1	1	2	Also tropical S. America
Restionaceae .	29	15	14	2	Also tropical Africa
Haemodoraceae .	9	3	1	3	E. Cape and tropical America
Proteaceae . .	51	15	30	7	Through Africa and E. Asia
Hydnoraceae .	2	1	..	2	..
Myoporaceae .	5	1	2	..	Also tropics
Podocarpaceae .	7	1	4	2	Tropics and Oceania
Pittosporaceae .	9	1	9	1	Indian Ocean
Cunoniaceae .	19	2	8	4	New Caledonia
Santalaceae .	23	5	7	7	Tropics and few in north temperate zone
Aizoaceae . .	119	34	8	7	Most in Africa
Myrtaceae . .	72	1	44	23	Most tropical
Leptospermoideae	40	1	36	2	Oceania

In Aizoaceae 97 genera have been formed from the comprehensive genus *Mesembrianthemum*. All these occur in Africa, but most of them outside the area of the Cape flora.

In many of the widespread families certain tribes or sections have a predominantly austral distribution and are part of this component. Examples are shown in the following table:—

[TABLE.

TABLE II.

No. of Genera.

	Total.	Cape.	Australia.	S. America.
Liliaceae				
Anguillarieae . . .	8	6	2	..
Iridaceae				
Sisyrincheae . . .	25	8	4	7
Papilionatae				
Podalyrieae . . .	26	2	19	..
Genisteae	42	21	7	2
Umbelliferae				
Mulineae	9	1	1	7
Compositae				
Inuleae	142	44	35	9
Arctotideae . . .	17	15	2	..
Calenduleae . . .	8	5	1	1

A further example is seen in Rutaceae, where the sub-tribe Diosmeae with 18 genera is confined to South Africa but the allied Boroneae with 19 genera occurs in Australia and New Caledonia.

Very many genera have a definite austral distribution. The following far from exhaustive list gives some of those common to one or more of the other southern lands:—

Danthonia.—Central Africa, Australia, South America.

Schoenus.—Many in Australia, 1 in Europe and 1 in North America.

Caesia.—Australia.

Commelina.—Tropics and south temperate zone.

Australina.—Australia.

Carpobrotus.—2 in Australia, 1 in South America, 1 in California.

Tetragonia.—South temperate zone and North Africa and Japan.

Pelargonium.—Throughout Africa, Asia Minor, 2 in Australia.

Dodonaea.—Australasia.

Malvastrum.—South America, 1 in Australia.

Gunnera.—South America, New Zealand; also Tasmania, Sandwich Islands, Java and Central America.

Scaevola.—Australia and coasts of Indian Ocean.

Grammatotheca.—Australia.

Helipterum.—Australia.

Athrixia.—Australia.

Cotula.—Australia, South America, extends to tropics.

A number of endemic genera or genera confined to Southern Africa are to be added to this component, either because they are most nearly related to or derived from definitely austral plants. Among such are *Chaetobromus*, *Pentameris*, *Pentaschistis*, *Afrachneria* and *Poagrostis*, all derived from the austral *Danthonia*; *Asterochaete*, which is very closely allied to *Carpha*, which occurs in Australia and South America; *Tetraria*, nearly allied to the Australian *Gahnia*; *Bulbine*, very close to *Bulbinopsis* in Australia; *Anaxeton*, *Petalacte* and *Phaenocoma*, all derivatives from the *Helichrysum-Helipterum* group; *Venidium* and *Arctotheca*, derived from *Arctotis*. The list could be much extended.

A few species in the Cape flora are also found in other southern floras. Among those found in both Australia and South America are: *Cotula coronopifolia*, *Dichondra repens*, *Scirpus antarcticus*, *S. cernuus*, and *Triglochin striatum*. The recent rediscovery of *Polypodium magellanicum* by Dr. Wicht in the mountains above Stellenbosch may be added. This species is also known from South America, Tasmania and New Zealand. *Apium filiforme* has been mentioned earlier. Species found in Australia but not in South America are *Haemarthria altissima*, *Themeda triandra* and *Papaver aculeatum*. The last is a case of an isolated southern occurrence of a species in a genus otherwise confined to the northern hemisphere.

African Component.

As distinct from the austral component this comprises those plants which have their distribution area and its main part or apparent centre outside the limits of the Cape flora. Some of these plants occur in the other southern lands, in which case they are southern representatives of groups centred in the tropics; the majority, however, are only in South Africa. Included also are plants, sometimes with limited range, sometimes endemic, which are most nearly related to plants with a wider African range. They appear as southern derivatives.

The African is an important component. In spite of its great individuality the Cape flora has a distinctly African character, and contains quite a big percentage of plants characteristic of other parts of the continent. Some of the most distinctive plants of the flora are in this component, such as Ericaceae and Thymelaeaceae. As an illustration of the importance of the component a preliminary analysis of some larger families is shown in the following table:—

[Table.

TABLE III.

No. of Genera.

	Cape Flora	Endemic.	Austral.	African and Northern.	Cosmo-politan.
Gramineae . . .	55	8	7	18	22
Cyperaceae . .	26	7	6	5	8
Liliaceae . . .	26	3	8	12	3
Iridaceae . . .	33	16	10	17	..
Orchidaceae . .	26	12	..	14	..
Papilionatae . .	30	15	5	5	5
Umbelliferae . .	25	7	5	11	2
Asclepiadaceae . .	12	3	..	5	4
Campanulaceae . .	18	10	5	1	2
Compositae . .	94	41	22	25	6

Prominent in this component are those families with their main range in the tropics but which extend, often with local genera, to the temperate zones. Examples which extend to Australia are seen in Polygalaceae, Sterculiaceae, Asclepiadaceae, Rubiaceae, Labiatae and Cucurbitaceae. It may be noted that the families, other than endemic families, which occur in the Cape flora but are not found in Australia nearly all have a tropical range. These are Piperaceae (tropics), Myricaceae (tropical Africa and north temperate zone), Ulmaceae (tropics), Anacardiaceae (tropics), Melianthaceae (South and North Africa), Flacourtiaceae (tropics), Oliniaceae (tropical Africa), Ericaceae (north temperate zone and tropical Africa), Valerianaceae and Dipsacaceae (both mountains in tropics and north temperate zone).

Genera belonging to this component are much too numerous to mention. Characteristic examples are: *Andropogon, Zantedeschia, Urginea, Crinum, Moraea, Clematis, Rubus, Dolichos, Clutia, Grewia, Sparmannia, Myrsine, Euclea, Leonotis, Solanum, Euryops, Othonna.*

Some of the endemic or almost endemic elements which are most nearly related to or derived from members of this component are included in it. In some cases the relationships are clear, but not in all cases. The derivative genera of Ericaceae may be used as an illustration. These are all certainly derived from *Erica*. Most of them are endemic to the Cape flora, but three, *Blaeria, Phillipia* and *Ericinella*, have the largest number of their species on the mountains in Central Africa and in Madagascar, and a much smaller

number in the south. The range of these suggests very strongly that they originated outside the present area of the Cape flora and have migrated southwards into it. *Ericinella* has its southern limit in the Drakensberg and E. Cape.

Other examples could be quoted, such as the southern derivatives of the pan-tropical *Lobelia*. Here there are parallel derivatives in other south temperate lands. The endemic genera of Polygalaceae, *Mundtia* and *Muraltia*, are further examples.

In other cases the relationships are rather more complex. As an example, Campanulaceae, sub-family Campanuloideae, may be taken. This sub-family has its main distribution area in the north temperate zone and a lesser concentration in the Cape flora. *Wahlenbergia* is a cosmopolitan genus extending from the tropics both north and south. It has a large number of endemic species in the Cape flora. In the south *Lightfootia*, which occurs in the Cape flora and in its outliers, and the endemic *Microcodon*, appear to be derived from *Wahlenbergia*. On the other hand *Roella*, of which most of the species are in the Cape flora, a few extending to the Drakensberg, is not closely allied to *Wahlenbergia*. It appears more nearly related to the northern genus *Campanula*. From *Roella* the endemic genera *Prismatocarpus* and *Merciera* are almost certainly derived.

This example in which a genus has its nearest counterpart in the north temperate zone is just one from many that could be quoted in which what may be called parallel development has occurred. What appear at first sight austral genera may in such cases have their nearest relatives in the northern hemisphere and should be placed in the African component. An interesting case of this kind is the Selaginaceae, a family confined to Southern Africa though not to the Cape flora. Of the 7 genera 4 are endemic. The general distribution suggests the austral component, but there is in the Mediterranean basin a structurally very closely allied family, Globulariaceae. Both are clearly derivatives from Scrophulariaceae, and appear as another case of parallel development in temperate climates from a presumed common ancestor.

Genera with northern counterparts of this kind are by no means confined to the examples mentioned. A few others are given in Table IV.

A parallel case but with developments of groups of species not of genera is seen in *Erica*, *Helichrysum* and *Ornithogalum*.

Included also in this component are a number of endemic genera which are most probably derived from members of it. Examples are seen in *Vallota*, *Knowltonia*, *Dianacria*, *Vauanthes*, *Orphium* and *Nenax*.

TABLE IV.

Cape Genus.	Northern Counterpart.
Moraea	*Iris*
Anthericum § *Trachyandra*	*Asphodelus*
Cysticapnos	*Corydalis*
Crassula	*Sedum*
Passerina	*Thymelaea*
Lobostemon	*Echium*
Gibbaria	*Calendula*

Northern Component.

While this group appears as an extreme of the previous one, it is retained both as a matter of convenience and because different in origin, to group together plants which have a northern, usually north temperate, main range and which are represented in the Cape flora by one or very few species. Examples are seen in: *Hyacinthus, Salix, Cerastium, Anemone, Papaver, Alchemilla, Trifolium, Viola, Hypericum, Sanicula, Sium, Anchusa, Mentha, Ballota, Scabiosa, Valeriana, Hieracium* and *Sonchus*. The list is not exhaustive. Many of these genera have a wide range which extends from the north temperate zone along mountain chains to the south. In such the Cape species marks the furthest extension in Africa. In others, however, there is discontinuity either great or small, and the Cape species are isolated from the main range. The extreme case of *Papaver* has already been noted. Others are *Hyacinthus, Anchusa, Valeriana* and *Hieracium*. A partial discontinuity occurs in *Cerastium*, in which the species in Central Africa belong to a different section of the genus from those at the Cape. The latter are more nearly allied to species in the north temperate zone.

Among the plants associated with this component special mention must be made of *Carex*. This is a genus widely spread and with many species in the north temperate zone, but also extending along mountain ranges in the tropics and into the southern hemisphere. There are a few species in the Cape flora. The greatest concentration of species is in Eastern Asia. The general distribution points to a probable origin in the northern hemisphere. In the Cape flora there is the allied but more primitive genus *Schoenoxiphium*. This has a structure that appears to show the lines along which the more specialised *Carex* evolved. Comparative morphology would most certainly suggest that *Carex* is derived from *Schoenoxiphium*; so much so, indeed, that in some of the species in Southern Africa the

distinctions between the genera have not been clearly made out. But *Carex* apparently had a northern origin and *Schoenoxiphium* is confined to the Cape flora. What seems the most probable explanation is that the latter is an old type, or closely related to one which entered the Cape flora with its first appearance. At that time it had a much wider distribution, but has become extinct except in the south. The more specialised *Carex* arose from it in the north and has migrated to the Cape flora at a later period. Much more intensive investigation is needed before this explanation can be looked upon as anything more than a working hypothesis.

A case exactly parallel both in features of distribution and in morphological relationships is that of the endemic *Exomis* and the world-wide *Atriplex*. The last is almost certainly a rather recent addition to the Cape flora. Its species are either maritime or characteristic of arid regions.

Cosmopolitan Component.

This needs no elaboration. In most of the cosmopolitan genera many or all of the species in the Cape flora are endemic or certainly southern. Exceptions occur in some water and marsh plants.

Proportions of the Components.

There is still so much uncertainty about the extent of range and relationship of so many plants that at the present time it is not at all advisable to attempt to give any figures suggesting exactness for the relative proportions of these components. Table III may be taken as a guide. From this it appears that the austral component with the addition of the endemics would average half or less of the total. Of the other components the northern is small.

Forest Flora.

Before turning to general points that arise from an analysis of the flora into these components, something must be said about the forest flora. Though this exists side by side with the mountain flora and is very closely interrelated with it geographically, it is distinct both floristically and ecologically. This flora is very much less rich in species. Many of the most characteristic plants of the mountain flora are wanting altogether.

Whether the whole flora is considered, or for simplicity the trees alone, it appears as a much more uniform one. The African component is very much the largest. Families and genera with ranges more or less continuous along the eastern mountains, sometimes extending to the tropics, are very numerous, and most of them belong to or are allied to groups characteristic of the tropics. The species are in many cases quite local in their distribution

and the southern ones distinct. The austral component is very small: among the trees it is represented by *Podocarpus*, *Cunonia*, *Platylophus*, *Brabeium* and *Faurea*, with possibly also *Cassine* and *Rapanea*. *Olea* stands in rather a special position. This genus has a wide distribution in the northern hemisphere, it extends throughout Africa, and has an area with characteristic species in Australia and New Zealand. Otherwise the northern component is wanting.

Other than *Brabeium* there are no genera endemic to the region of the Cape flora, though there are some confined to the south coastal belt.

Owing to its limited habitat conditions the distribution of the forest outside the area of the Cape flora is confined to the mountain chains on the east side. On the west, arid conditions make a barrier between the Cape and the Equator. The eastern distribution is much less discontinuous than is that of plants of the mountain flora. For example, out of a list of 56 species of trees in the Knysna forests quoted by Hutchinson, 43 extend to Natal and the N.E. Transvaal and 20 of these to the tropics. In the Cape flora area, that is west of Knysna, out of 36 species of trees, 20 extend to the east and north-east. The features of distribution of species in these tree genera with more or less continuous range may be illustrated by *Podocarpus*, and is set out in the following table:—

TABLE V.

Podocarpus.

P. gracilior / *P. gracillima*	Mountains of Central Africa and south to borders of the Union
P. latifolius	Drakensberg–S.W. Cape
P. Henkelii	Drakensberg–E. Cape
P. falcatus	Drakensberg–Swellendam
P. elongatus	Swellendam–Cedarberg

The number and variety of component species in the forests is greater in the north and north-east and diminishes to the south and south-west. This diminution in richness is associated with an increase in local species.

The forest flora has features that point to its being ancient and long settled. As with the mountain flora, there is a lack of species dominance, and a uniformity in habit shared by many plants. Here this is shown by the marked similarity of leaf in the trees. The percentage of endemics is small, but the features generally are well marked. The absence of endemics in what appears on other grounds to be an ancient flora may be correlated

with the inability of the plants to exist outside very strictly circumscribed habitat conditions. The necessity for a continuously moist environment has not been conducive to differentiation as have been the more varied conditions in the mountains.

Neither in structural features nor in its ecological relations is there anything that can separate this flora as different in age from the mountain flora. The two are very closely related. While the fully developed climax communities are very distinct, those in the development are very closely related indeed both structurally and also floristically. If arguments based on ecology alone were stressed, the conclusion might well be reached that the forest is an ancient and disappearing type of community that is being replaced by the more vigorous mountain flora.

At the present time, under the influence either direct or indirect of man, forests are disappearing rather rapidly. Where protected they can and do reproduce, but at a very slow rate. The extreme slowness of regeneration may be correlated with the general increase in dryness which has caused the reduction in area of the Cape flora as a whole. It might seem that this dryness has reached a stage at or very near the possible limit of existence for forests.

Bews has made out a case for regarding the floras of Natal and most of the eastern Cape as being relatively modern and derived from the southward advance of a tropical flora. His arguments are based in the main upon studies of the coastal and subcoastal belts. It is not justifiable, as is done by implication, to extend these arguments to cover the forests within the area of the Cape flora. There is nothing that could support a theory that they are an invasion into an area already occupied by an older Cape flora.

Comparisons.

The Cape flora has generally been regarded as possessing definite affinities with those of other southern lands, especially with that of S.W. Australia. The similarities which exist have been claimed as being indicative of real relationships between the floras. They are based, for the most part, on the austral components.

In order to test the real nature and value of these similarities it seemed advisable to make a somewhat detailed comparison between the Cape flora and that of S.W. and South Australia.

Before entering on any floristic comparisons, it must be pointed out that these two regions have very similar climates, and that in response to these there is close similarity in the structure of the vegetation and general life-forms of the plants. Such a likeness in form is of no geographical significance and is no indication of floristic alliance. Very closely similar

structure and life-form of plants is found in the western Mediterranean and in Southern California. The vegetation type which represents a reaction to warm temperate conditions with winter rainfall is a distinctive one, and has been called sclerophyll. The climatic similarities of these regions are illustrated by the ease with which plants imported from any one become established in another. In the Cape region from Australia come wattles, gums, *Hakea* and others, from the Mediterranean pines and numerous weeds. Cape plants have spread in the other countries.

After making full allowance for these external likenesses, a comparison of the flora shows that in both the same characteristic austral plants are present. Also that in general terms the distribution of families is similar. The proportion of each varies: families abundant in one flora may be very sparse in the other. For example, Crassulaceae with 7 genera and about 300 species in South Africa is represented in Australia by about 12 species all belonging to the section *Tillaea* of *Crassula*. Iridaceae, so prominent in the Cape flora, is represented in Australia by 5 genera with 35 species. On the other hand Myrtaceae, one of the largest families in Australia, has 1 species in the Cape flora, and Goodeniaceae 1 species not found west of Riversdale. Many other cases of families or individual genera could be mentioned.

In addition to such positive similarities, the floras agree in the absence or relative paucity of some of the large families characteristic of the northern temperate zone. Prominent among these are Pinaceae and the catkin-bearing trees. The latter are represented in the Cape flora by *Salix* at the extreme limit of a range scattered through Africa, in Australia by *Notofagus*, a genus occurring in Tasmania, New Zealand and South America. Other examples are:

TABLE VI.

	Total.	S. Africa.	Australia.
Caryophyllaceae .	80	7	6
Ranunculaceae .	35	5	3
Cruciferae . .	350	11	23
Saxifragaceae .	80	1	7
Rosaceae . .	83	4	5
Primulaceae .	20	1	2
Borraginaceae .	68	4	9

When a more detailed comparison is undertaken the similarities seem to be less. The numbers of genera that are common to the two floras is

not at all large. Whether one deals with the definitely austral part or with the whole the result is the same. For example, in Proteaceae no genus is common to both; in Restionaceae, according to Pillans, there are two genera in common out of 29, but none in the recent revision by Gilg-Benedict. The following table gives data for some of the larger families. In the table the figures in both floras extend somewhat beyond the strict limits of the floras concerned.

TABLE VII.

No. of Genera.

	Cape.	S.W. Australia.	Common.
Compositae	94	93	7
Gramineae	60	90	18
Papilionatae	37	44	1
Aizoaceae	70	61	6
Chenopodiaceae	10	27	6
Rutaceae	12	27	0
Euphorbiaceae	9	21	1
Scrophulariaceae	32	15	3
Umbelliferae	25	21	4
Rhamnaceae	5	8	1
Liliaceae	48	43	3
Iridaceae	35	5	0
Orchidaceae	27	32	1

A further analysis of some of the larger families reveals that there is often a development of endemic genera in different tribes in the two floras. This is illustrated in Table VIII.

From a consideration of these figures the conclusion must be drawn that the similarities do not indicate very close relationship. There undoubtedly is an affinity. When the total floras are taken into account the conclusion becomes even more definite. The Cape flora has a strong African component; it includes such characteristic families as Ericaceae, Myricaceae, Anacardiaceae, none represented in Australia. To them may be added Selaginaceae. In Australia, prominent families not found in the Cape flora are Epacridaceae, Dilleniaceae, and the austral Centrolepidaceae.

The results of comparisons of this kind point to a common origin for the floras in the remote past, but with prolonged isolation and with quite separate paths for immigration.

TABLE VIII.

No. of Genera.

	Cape.	S.W. Australia.	Common.
Liliaceae			
Melanthoideae	9	7	1
Asphodeloideae	9	14	2
Aloineae	6	16	0
Scilloideae	21	0	0
Orchidaceae			
Ophrydinae	23	0	0
Neottiinae	0	24	0
All others	4	8	1
Papilionatae			
Podalyrieae	2	19	0
Genisteae	22	7	0
Umbelliferae			
Hydrocotyleae	2	9	2
Ammineae	12	2	1
Compositae			
Astereae	10	7	0
Helichrtseae	8	26	2
Relhanieae	12	0	0
Anthemideae	20	7	0
Arctotideae	15	1	0

Outliers.

As mentioned earlier there exist a considerable number of plants belonging to, or very closely allied to, the Cape flora in stations outside the main area. These are scattered along the mountains and higher ground on the east side as far as the Equator, with a few in Abyssinia and some in Madagascar and some of the more distant islands in the Indian Ocean. The distribution is not regular—there are few between Rhodesia and Kenya and very few on the west side. This is partly the result of topography, there being fewer possible stations in the gaps. In very general terms the plants in these outliers are more numerous in those approximate to the main area than farther off.

The actual species in these outliers are rarely identical with those in the main area of the Cape flora, but those in the outliers are often found in stations scattered over a wide area. Their ranges, though discontinuous,

are generally much wider than those of their congeners in the main area of the flora. The discontinuity is a striking feature—many species occur in the Drakensberg and in Central Africa, some have a gap between the main area and the Equator. Such discontinuity can only be explained by postulating a one-time continuous area linking up the detached portions, in other words the outliers are relics.

Included among the plants occurring in these outliers are many that belong to the austral component: these present especially interesting problems which can at present be merely touched upon. The most that can be attempted is to quote a few examples in illustration of some of the salient features. Of the austral families, Restionaceae has few representatives in these outlying stations. Proteaceae, on the other hand, extends throughout Africa, though the wide-spreading forms here are not restricted to the local stations characteristic for so many Cape plants. *Protea* extends north to Abyssinia. *Faurea* is widely spread, with its main range in southern Central Africa; it might be regarded as an outlier within the Cape flora area. *Leucospermum* has mountain stations as far north as Kenya. *Leucadendron* has outliers on the Drakensberg. The remaining genera are endemic to the main area of the flora. Of these genera *Leucadendron* is certainly a specialised type; its extension eastwards might be regarded as a recent invasion. The other wide-spreading genera belong to the division of the family with zygomorphic flowers. Within this *Faurea* appears as a relatively primitive form. The wide-spreading species of *Protea* are relatively primitive in the genus. *Leucospermum* is a specialised form.

A distribution much wider than exists at present has been claimed for Proteaceae. This claim is based upon leaf fossils in Tertiary deposits in many parts of Europe. While many of these records are open to grave doubt as to the accuracy of the determination, their prevalence does seem to point to a wider northern range in the past. If this is so, the relatively primitive *Protea* and *Faurea* would appear as old persistent types. The more specialised forms within the Cape flora would be rather more modern.

The austral genus *Aristea*, which occurs in the northern mountain outliers, contains 25 species in the Cape flora and 18 in areas outside. It extends to Madagascar. The outlying species are regarded as belonging to relatively primitive sections and for the most part have wider ranges. The allied derivative genera *Nivenia*, *Klattia* and *Witsenia* are confined to the Cape flora.

A very similar set of things is seen in *Stoebe*, where the species in the northern outliers belong to the more primitive section of the genus and have much wider geographical ranges: one species has been recorded on the Central African mountains, in Madagascar and on Reunion.

One further example may be taken from a genus not in the austral

component, *Erica*. The distribution of the genus is interesting. Much the largest number of species occurs in the Cape flora, a small number on the mountains through East and Central Africa, and a rather larger number in the Mediterranean basin and Western Europe. The relationships of the associated genera, and especially of *Blaeria, Phillipia* and *Ericinella*, have already been dealt with. In *Erica*, the species that occur in the outliers are among those with relatively small flowers. They are certainly more primitive than many of those in the Cape region.

Discussion.

In the solution of the many problems of the relationships, migrations, and possible origin of the Cape flora, these outliers must take an important place. In the first case the present discontinuity of area is derived; in the past there must have been continuity between the main area and the outliers.

The fact that in so many cases the species found in these outliers are relatively primitive ones which have wide ranges points to the possibility that they are ancient types, or at least not much modified from ancient types. Taken together with the known fact that at present the area of the Cape flora is decreasing, this has suggested that these outliers are relics from a once much more extensive area. The present detachment of these outliers has resulted from climatic and other changes in the intervening parts. Weimarck especially has assembled a large mass of data in support of this view, basing his conclusions largely on studies of *Aristea* and *Cliffortia*. He has found further support for this relic view in investigations of the local distributions of several members of the austral component.

The much greater richness of the main area in species may be looked upon as a result of its having a favourable climate, its area being continuous yet having been isolated from invasion from the north from an early period, an isolation due to intervening deserts. In mid-Tertiary times, when the Cape flora must have been long established in the south, deserts extended over the Kalahari basin and across the Transvaal and Rhodesia at least as far as the escarpment in the east. Later this belt underwent amelioration of climate, but the present Karroo area became dry, cutting into the Cape flora and leaving outliers on the marginal mountain ranges. Great species differentiation went on in the area so cut off.

While the view that these outliers are relics of a once much more continuous area covered by the Cape flora is well supported by evidence obtained from the flora itself and from other sources, there are a number of points that require further explanation. In the first case, the high ground in Central Africa has itself been subject to large changes both in

topography and climate within quite recent geological times. The formation of the Rift Valley with its accompanying elevations and volcanoes took place towards the close of the Tertiary epoch. By this time the Cape flora had already been established, as is obvious from its highly endemic character and from the fact that members of it had spread to Madagascar and even to more distant islands. The recent changes in Central Africa are sufficiently ancient to have brought about some species differentiation, as for example the species of tree-like *Senecio* on the volcanoes. These are minor modifications; there has not been extreme differentiation comparable with that in the Cape flora.

The stations now occupied by the Cape flora in Central Africa are certainly not all positions maintained throughout its history. It is known that in Late Tertiary times there were climatic fluctuations with periods of considerable lowering of temperature. During these the possible areas for Cape plants would be much extended. The present isolated stations need not be original ones, but may well be those left after the last cold period in which suitable climatic conditions remained and to which the flora was driven by an advancing flora adapted to warmer conditions.

The extension of these rather recent cold periods will give an explanation of the southward migration of the northern component, and especially of those members of it which have a discontinuous range. They are relics of the colder climate. That the arrival of these plants may be rather recent is supported by the very local nature of their occurrence at present, also by the fact that many of them do not seem as completely adjusted to the habitat conditions as many other plants. They are not drought-resistant, and many are confined to moist or sheltered conditions. Some additional support is obtainable from the presence on the mountains in the eastern part of the country, though not in the Cape flora, of species of *Thalictrum*, *Vaccinium* and *Luzula*, all genera of the colder north temperate regions and not otherwise present in the south. The isolated stations for these plants look very much like relics from a recent extension of range.

The species which occur in the outliers of the Cape flora are, however, ancient. At any rate they date back to periods when there was continuity with the main area. Geographically these species are of two kinds: austral plants in which these outliers are the northernmost points in their range, and members of the African component which frequently have much wider ranges. Ericaceae may serve as an illustrative example. The range of the family is chiefly in the north temperate zone, with some tropical representatives; the sub-family Ericoideae also extends south in Africa. In the sub-family *Erica* is much the largest genus and the one probably nearest to the ancestral type. It has a large concentration of species in the Cape flora, a few in Central Africa, and rather more in Western Europe. The so-called

minor genera are all derivatives. It has already been noticed that the species of *Erica* in Central Africa are relatively primitive ones, and that some of the derivative genera, including those that extend to Madagascar, appear to have arisen in this region.

The distribution both of the family, sub-family and genera, and the interrelations of the genera, are most readily explained on the assumption that *Erica* originated in Central Africa and that then migration took place to the south. This southward migration to the Cape flora, which has been followed by so great a differentiation of genera and species, must have taken place early in the history of the flora. The very numerous local endemics alone point to very long establishment.

The same general conclusions thus reached in the case of Ericaceae apply in the case of those genera which are southern in range but have counterparts as a parallel development in the north. They would seem to have originated from a progenitor in Central Africa and undergone migration accompanied by modification. An example which has been studied is the tribe Calenduleae which contains several genera in South Africa and one in North Africa and the Mediterranean. Some of the southern forms occur in the Central African outliers. In this tribe *Dimorphotheca*, which is wholly southern, is regarded as the most primitive genus. The northern genus, *Calendula*, is a derivative from it but is geographically completely separated. Those genera which do occur in the intervening region represent other lines of development. Norlindh in discussing these relationships suggests that the primitive genus in the past may have had a much more extensive range and one that overlapped with that of *Calendula*. In later times it has become extinct except in the south.

In this case the presumed ancestral form is persistent; in many it seems to have become completely extinct. That large portions of the early Cape flora must have become extinct is obvious from what has been said about the one-time continuity of the outliers. The present-day relics are so small in area that it is quite justifiable to assume that they do not possess the whole of the ancient flora and that disappearance of original types has occurred.

The endemic genera associated with the African component must have had as long a history in the Cape flora as the examples cited.

Not all the plants in the African component have this history. Some appear to have arrived at rather later dates. The example of *Carex* may be again referred to. The primitive *Schoenoxiphium* is one of the original flora; the more specialised *Carex* originated in the north and reached the Cape at a later period. Also *Blaeria* and *Phillipia*, which originated from *Erica* in Central Africa, probably entered the Cape flora at a later date than that genus. Those genera that to-day have a continuity of range, and

especially those with a tropical distribution, and a few south temperate species are also later arrivals. Examples that may be quoted are *Peucedanum, Andropogon, Grewia* and *Euryops*, among many others.

In other words, historically there has been migration from the north at more than one time. The bulk of the flora, both the austral and part of the African component, having arrived very early, other parts arrived later up to the recent incoming of the northern component.

While there thus seems to have been migration into the region of the Cape flora and persistence of relics of it in the outlying stations, much less is known of possible outward spread from the flora. There is ample evidence of local outward spreading at the margins. The recently elevated land forming the coastal strip on the west coast has been populated very largely from the mountain flora, and some differentiation of species has occurred in the process. Again, the flora of the Great Karroo, between the coastal mountains and the escarpment, is also largely derived from the Cape flora. The dominant *Mesembrianthemums*, the xerophytic forms of *Pelargonium*, many annuals and geophytes, are obvious examples. In both these cases spreading has been into adjacent areas. For more distant parts the evidence is at present not conclusive. While several examples might be quoted of Cape genera with a few species outside the area, and of these some which appear to be progressive, it is not possible to determine their real status without detailed investigations. All might be equally stragglers from the main flora on retreat of its area.

Origin.

Some suggestions have been made on the origin of individual members of the flora, and it has been seen that it is certainly diverse. On the origin of the austral or original part a very great deal of speculation has been expressed. Though the flora is undoubtedly an ancient one it is not at all markedly primitive. Its very striking individuality is the result of evolutionary specialisation of its members.

It has been seen that the result of comparison of the Cape flora with those of other southern lands is to reveal a degree of similarity combined with strong divergence, which points to community of origin though remote and followed by long separation. The signs of this common origin are shown by the most ancient parts of the flora.

In reference to this unity of origin two main hypotheses have been put forward, both of which have been subject to many modifications. In very broad outline the one is that the Cape flora is part of one that originated in the south; other fragments of this are found in the other southern lands. The place of origin is considered to have been in the south temperate zone

and the main early migrations to have been northward. The second hypothesis is that the place of origin was in the north, probably in the tropics. From this locus migration took place to the temperate zone, reaching the rather isolated southern lands in which survival has been possible largely owing to isolation.

The basis upon which the first hypothesis rests is very largely the distribution of the plants of the austral component, and especially those that occur in more than one of the southern lands. As was mentioned earlier, the last are more numerous in the floras of Australia and South America than in that of South Africa. While it is not possible to enter on any discussion of the details of the arguments that can be brought in support, some of the main general implications must be considered. If the southern origin for these floras is looked upon as having been in the pre-angiospermic flora, then a multiple origin of angiosperms must be assumed. This is by no means impossible, and has indeed been supported by some palaeobotanists and phytogeographers. It is a conclusion that is, however, a little difficult to apply to these floras. In them purely austral groups are only a small part. Much of the austral component itself is made up of plants belonging to families or groups with a much wider range, which suggests rather an origination from ancestors that were themselves angiosperms, or at any rate pro-angiosperms that had spread widely. But the main land-mass over which these ancestors must have spread became broken up about the time of origination of the angiosperms themselves. South Africa became separated in Cretaceous times at the latest. The time available for a spread of the early ancestors and the origination and dispersion of a southern derivative flora seems very short.

The break-up of Gondwanaland, which occurred a little earlier in South Africa than between the other lands, certainly seems to give the clue to the greater similarities between the South American and Australian floras than of either with the South African, and to the striking individualities of each.

Further, if a south temperate origin is assumed, the outliers of this early flora which now occur within the tropics and which were once continuous would represent the frontiers of its advance. The rather wider areas of distribution of the plants in them might be regarded as supporting this, but the systematic relations are not compatible.

The alternative hypothesis does meet or avoid some of these difficulties. Origination being pictured as in the tropics, on general ground the most likely region, there is no necessary implication of any multiple place of origin, though such is not excluded. The migration from the place of origin to the temperate zone may have begun before the break-up of Gondwanaland but almost certainly continued afterwards. A direct land continuity during the period of migration and establishment is not an

essential. In any case, the southern lands became isolated partly by continental drift and later by the formation of deserts across the paths of migration. Since the time of arrival of the early flora, evolution and modification have gone on independently in the different lands, and each has had its own source of addition by later migration from adjacent lands. Thus the basic similarity and striking individual divergence is explicable.

According to the hypothesis of southern origin the austral component in the flora is the oldest part. But arguments have been brought forward which show that some part of the African component is of at least equal age. This is quite possible on the hypothesis of tropical origin. In migrations occurring over so vast an area as the original Gondwanaland there must have been local differences in flora. Some plants migrating along what is now the African continent might well be missing in other regions and *vice versa*. This hypothesis also supplies an explanation more readily of the distributions of those plants which have allied counterparts in the north temperate zone, also such cases as those mentioned of *Carex* and *Atriplex*. On this view the outliers are relics which are probably nearer the original flora than the main southern portion. Their persistence has been in regions much less favourable to differentiation, and has been much more directly in competition with more modern floras.

Taking all the facts together, the hypothesis of a tropical origin seems the most satisfactory and the one that leaves fewest unexplained difficulties. The early flora that became differentiated for a temperate climate migrated southwards, and at one time was continuous in possible habitat conditions from the Equator to the Cape. By mid-Tertiary times the southern portion of this extended area was isolated, and it has since undergone independent modification and adjustment with enormous species differentiation. Its area has been reduced by the development of arid conditions farther south in more recent times. The northern portions have during the same times become very much reduced, and now persist only in stations of small size separated from one another by land occupied by a more modern flora. Additions to the early flora in the south have occurred through land migrations from the north and east.

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THE DEVELOPMENT OF THE STRIPED DOGFISH (LUI-HAAI), *PORODERMA AFRICANUM* (GMELIN).*

By Cecil von Bonde,
Government Marine Biologist and Director of Fisheries,
Union of South Africa.

(With Plates XIII–XVI.)

(Read September 19, 1945.)

Introduction.

Poroderma africanum (Pl. XIII, fig. 1) attains a length of about 1000 mm. and its distribution is limited to the warmer waters of South Africa (False Bay to Algoa Bay), Mauritius, and Madagascar. It has also been recorded from the western or Atlantic side of the Cape Peninsula. It is fairly common in our seas, and on account of its habitual inactivity it is called the "Lui-haai" or Lazy Shark. In an aquarium this species seems to spend most of its time in sleeping, only being activated into movement when food is introduced into its tank.

In one of the tanks of the Sea Point Aquarium, where this species has been kept for the past five years, two egg capsules were laid by a female 850 mm. in length, for the first time on record. These capsules were immediately placed in a large pneumatic trough with running sea water, so that the development of the embryo could be more readily observed.

Female Reproductive Organs.

The female reproductive organs correspond basically to those of *Haploblepharus edwardsii* (von Bonde, 1945) and are more or less analogous to those of oviparous elasmobranchs. There are, however, some minor characteristic differences, and it is interesting to note that a female 700 mm.

* This paper is the third in the series "Contributions to the Embryology of the Elasmobranchii":

1. "The external development of the banded dogfish or pofadderhaai, *Haploblepharus edwardsii*," Biol. Bull., 88, pp. 1–11, 1945.
2. "Studies in the development of the picked or spiny dogfish, *Squalus acanthias*," ibid., pp. 220–232, 1945.

in length which was dissected was quite immature. In this case each vaginal aperture was completely closed by what appeared to be a very thick and tough hymen, so that a seeker had to be forcibly pushed through it in order to effect entry into the vagina. The whole length of each oviduct was completely undifferentiated and the ovary was undeveloped.

The female which laid the egg capsules above referred to showed the usual differentiation of the oviducts (Pl. XIII, fig. 2) into the various parts as in *H. edwardsii*. The cloaca, however, revealed a peculiar structure not before observed in any other elasmobranch female. There was no urinary sinus as is usually found in female selachians. The cloaca was divided transversely by a thick transverse membrane (t.m.) separating the rectal opening from the vaginal apertures which lie widely separated from each other behind the membrane. (See Pl. XIII, fig. 2, which shows the handle of a seeker pushed through the left vaginal aperture into the vagina.)

The cœlomic opening of the fallopian tubes in the present species (f.t.o.) was not slit-like as in most selachians, but was small and rounded. The albumen and the nidimental glands were very well developed, as might be expected in oviparous females.

Male Reproductive Organs.

Internally, these were true to type. The claspers (Pl. XII, fig. 3), however, were comparatively short and blunt and completely devoid of any spurs, claws or hooks, and closely resembled those of *Scylliorhinus capensis* (*Scyllium capense*, Leigh-Sharpe, 1924, p. 559). The rhipidion (r.) was reduced but the siphon (s.) was well developed.

Egg Capsule.

The egg capsule (Pl. XIII, figs. 4 and 5) resembles that of *H. edwardsii* in general shape. Its complete transparency, however, makes it possible for one to observe the whole development of the embryo within the capsule, which one was unable to do in the case of *H. edwardsii* (*op. cit.*), where the opacity of the capsule necessitated the removal of the ovum immediately after the capsule was laid.

The present capsule was 103 mm. in length and 50 mm. wide, and had very well-developed respiratory slits (r.s.) whose arrangement was peculiar in that on the dorsal surface of the capsule there was a slit at the anterior and posterior right-hand side and none on the left side, whilst on the ventral side these slits occupied the corresponding positions. (The surface of the yolk on which the embryo first appeared is termed dorsal, the sharp end of the capsule to which the head of the embryo points in its earliest development stage is the anterior and the broader flattened end is the posterior.)

In Pl. XIII, fig. 4, which is a photograph of an egg capsule taken by placing the capsule on a sheet of ground glass with a strong light underneath, these dorsal slits are shown on the lower side of the figure, whilst the transparency of the capsule permits of the ventral slits being seen on the upper side.

The primary function of the egg capsule in oviparous sharks is a protective one, but provision is also made for the respiration of the embryo and its eventual hatching.

On or about the 70th day of incubation it was observed that when the capsule was lifted out of the water, the contained liquid poured out through the respiratory slits. By this time the albumen surrounding the yolk mass had completely disappeared, and the embryo and its yolk sac were bathed in sea water which now freely entered the interior of the capsule through the respiratory slits. Such passage of sea water to and from the interior of the capsule was also further facilitated by the writhing movements of the embryo, which at times was extremely active, coiling and uncoiling itself rhythmically. At this stage, when the embryo was 48 mm. long, the plumose external gills were very well developed and relatively long. They had then reached their maximum development.

In this species the capsule does not undergo a steady deterioration, as in "*Chimaera* and in other elasmobranchs" (Smith, 1942, p. 709). The capsule does not undergo any change either in its substance or colour, but it retains all the characteristics of the freshly laid capsule through the whole of the period of incubation except as mentioned below. As in the case of *Heterodontus japonicus* (Smith, *op. cit.*, p. 709) the respiratory slits gradually widen and so permit of the readier entrance of water for respiratory purposes.

On or about the 121st day of incubation, when the embryo had attained a length of 109 mm., the flat posterior end of the capsule appeared to change so that here the two apposing ends which heretofore had been fairly thick and completely fused together, became somewhat thinner and gradually freed from each other by slow degrees, the loosened edges becoming curled up and rolled back on themselves.

The embryo was hatched on the 164th day, having attained a length of 145 mm. The yolk was completely absorbed and the yolk sac had disappeared, only the small umbilicus remaining. This hatching was a very ordinary one compared with Basford Dean's description of that of *H. japonicus* quoted by Smith (*op. cit.*, p. 709). The broader end of the capsule progressively grew thinner and the loosened ends of the apposing halves became more and more separated from each other and curled up and rolled back on themselves. The embryo then slowly emerged head first and left the capsule (see Pl. XVI, fig. 32), to swim freely in the surrounding sea water.

Development.

Egg capsule "A" was laid on 16th August 1944, and "B" on 19th August 1944. Both capsules measured 103 mm. in length, excluding the tendrils, 50 mm. in width and 23 mm. deep. The diameter of the yolk in each case was 40 mm. along its principal axis and 22 mm. along its minor axis. The yolk mass is in the form of a prolate spheroid, in conformity with the interior of the capsule. Thus the yolk mass appears circular when viewed from above or below, and oval when viewed from in front or behind.

In the following table the stages in the embryonic development within capsule "B" are set out in chronological order, whilst in Pl. XIV, figs. 6 to 20, and Pl. XVI, figs. 28 to 32, these stages are depicted at various intervals.

Egg Capsule "A".

Laid on 16th August 1944.

Date.	Size of Blastoderm.	Size of Embryo.
16.8.44	2 mm. in diameter	. .
22.8.44	10 ,, ,, ,,	. .
23.8.44	12 ,, ,, ,,	Embryo first appeared
25.8.44	19 ,, ,, ,,	5 mm. long
27.8.44	27 ,, ,, ,,	7 ,, ,,
29.8.44	32 ,, ,, ,,	8 ,, ,,

This egg capsule was then opened, *i.e.* 13 days after laying, and the yolk mass was removed. In this stage the blastoderm had covered approximately one-third of the surface of the yolk. The embryo, 8 mm. in length, showed the formation of 20 somites. The head was in a fairly advanced stage of development and in an optical section the neural canal was well demarcated. Owing to the rupturing of the vitelline membranes and the consequent extrusion of the yolk, it was impossible to rear this embryo beyond this stage. It is interesting to note that no such difficulty was experienced in the case of the embryos of *H. edwardsii* (*op. cit.*).

The other capsule "B" was left undisturbed so that the embryo could undergo normal development. Owing to the transparency of the walls of the egg capsule, the whole embryonic development could very readily be studied by periodic observation under a fairly strong light.

EGG CAPSULE "B".

Laid on 19th August 1944.

	Date.	Age in Days.	Diameter of Blastoderm (mm.).	Length of Embryo (mm.).	Figure.
FIRST MONTH	19.8.44	..	2	..	6
	22.8.44	3	4	..	7
	25.8.44	6	10	Embryo first appeared.	8
	27.8.44	8	17	3	9
	29.8.44	10	20	4	10
	3.9.44	15	Covered ½ yolk.	6	11
	6.9.44	18	Covered ⅔ yolk.	9	12
			DIAMETER OF YOLK BLASTOPORE (mm.).		
	9.9.44	21	15	10	13
	12.9.44	24	6	12	14
	13.9.44	25	Closed completely.	14	15
			DIAMETER OF YOLK (mm.).		
	16.9.44	28	40	16	16
	19.9.44	31	40	18	17
SECOND MONTH	23. 9.44	35	40	20	18
	26. 9.44	38	38	23·5	19
	30. 9.44	42	36	25	20
	3.10.44	45	34	30	..
	9.10.44	51	32	34	..
	14.10.44	56	30	38	..
	19.10.44	61	30	45	29
THIRD MONTH	24.10.44	66	30	47	..
	27.10.44	69	30	49	..
	5.11.44	78	28	58	..
	12.11.44	85	27	63	..
	19.11.44	92	26	66	..
FOURTH MONTH	26.11.44	99	25	75	..
	30.11.44	103	25	80	..
	3.12.44	107	25	85	30
	10.12.44	114	23	92	..
	19.12.44	123	21	109	..
FIFTH MONTH	28.12.44	132	19	136	31
	6. 1.45	141	15	138	..
	12. 1.45	147	9	140	..
	19. 1.45	154	5	142	..
	29. 1.45	164	Completely absorbed. Embryo hatched at this stage.	145	32

Smith (*op. cit.*, pp. 739, 740) states: "There remains the question concerning the comparative sizes or stages of development of embryos at the time when overgrowth of the yolk by the blastoderm is completed. The egg (yolk mass) of *Heterodontus japonicus* in the early stages of embryonic development measures from 40 to 50 mm. in diameter. The egg depicted in fig. 61, Pl. V, is in the stage in which the yolk blastopore has just closed. As compared with other eggs in approximately the same stage, it has an unusually large yolk mass, probably about 50 mm. in diameter. The length of the embryo (when straightened) equals about one-fourth of the diameter of the yolk mass. One wishes for similar data concerning modern sharks, but a cursory search of the literature reveals nothing that is helpful in this connection."

I also have not been successful in finding this data in current literature and therefore this aspect in the development of *Poroderma africanum* was carefully observed and recorded. Here the blastopore closed completely 25 days after the egg was laid, and the embryo was then 14 mm. in length or 0·35 times the diameter of the yolk, thus being larger than that of *Heterodontus japonicus*, which was only 0·25 times the diameter of the yolk.

On the 107th day, when the embryo had attained a length of 85 mm., the adult coloration, black longitudinal stripes on a grey background on the upper half of the body and uniform grey on the ventral side, appeared and at the same time the external gills had completely disappeared.

While the embryo is growing the yolk mass is being consumed, hence the diameter of the yolk sac decreases progressively. These changes are recorded on Pl. XVI, figs. 28 to 32. As the yolk mass decreases in size it still retains the shape of a prolate spheroid, except that one end gradually tapers into the umbilical cord (Pl. XVI, fig. 30).

Growth after the 107th day appeared to be accelerated. Thus in seven days the length increased from 85 mm. to 92 mm. After another nine days the length increased to 109 mm. In another nine days the length had increased to 136 mm. on the 132nd day. Thereafter there was a retardation in the growth rate so that up to the time of hatching, viz. the 164th day, in 32 days only 9 mm. had been added, whilst the yolk shrunk at a greater rate than heretofore.

Vitelline Circulation.

As in most selachians, the yolk circulation in the present species is more or less typical. A single vitelline artery emerges from the umbilical cord on the 24th day of incubation and passes cephalad for a short distance along the blastoderm under cover of the head of the 12-mm. embryo. It then divides into two arcuate branches which turn laterad and then

posterad towards the margin of the blastoderm (Pl. XIV, fig. 14). In this stage the blastoderm has almost completely covered the yolk mass except for the small ovoid area known as the yolk blastopore lying posterior to the umbilical cord. The main arteries give off no side branches on the dorsal surface of the yolk in this or any succeeding stages. The yolk blastopore is completely surrounded by a venous ring which receives numerous small venules emptying into it. The main vitelline vein drains this venous ring and runs straight forward to the umbilical cord to run along its right side to the heart.

In the 14-mm. stage (Pl. XIV, fig. 15) the yolk blastopore has completely closed and the venous ring has disappeared, being now represented by an elongated thickening of the main vitelline vein. The arcuate arteries have increased in length.

In the 16-mm. stage (Pl. XIV, fig. 16) this elongated portion of the vitelline vein has shortened into a more or less rounded area receiving numerous venules. The arcuate arteries are a little longer than in the previous stage, and the embryo is well removed from the yolk mass to which it is attached by an umbilical cord.

In the 18-mm. stage (Pl. XIV, figs. 17 and 17′) the arcuate arteries extend laterad and pass right round the yolk in a continuous circle forming the sinus terminalis. On the ventral side of the yolk, arterioles arise from the central portion of the sinus terminalis. The main vitelline vein receives numerous venules which all empty into the area above referred to, these venules arising on the ventral side of the yolk mass.

In the 20-mm. stage (Pl. XIV, figs. 18 and 18′) the main vitelline artery has extended much further cephalad and the arcuate branches pass round the anterior end of the yolk mass to form an arterial circle, half of which lies on the dorsal side and half on the ventral side of the yolk mass. The arterioles are much better developed and longer in this stage, while the vitelline vein now appears double and receives numerous side branches which arise on the ventral side of the yolk mass in close proximity to the arterioles with which they are probably connected by capillaries.

In the 23·5-mm. stage (Pl. XIV, figs. 19 and 19′) the main artery passes over the anterior end of the yolk mass and the arterial circle is now smaller, lying wholly on the ventral side of the yolk mass. The arterial circle is very thin in one part and gives rise to numerous arterioles. The venules appear to be developed only on the right-hand side of the anterior two-thirds of the dorsal side of the yolk mass, whilst in the posterior third they cover the whole of that area, lying in close proximity to the arterioles on the ventral side.

In the 25-mm. stage (Pl. XIV, figs. 20 and 20′) the arterial circle is beginning to disintegrate, the thin portion previously mentioned having completely

disappeared and the remaining parts are here beginning to coalesce, this coalescence being seen on the right lateral ventral side of the yolk mass in figs. 20′ and 21. On the dorsal side the venules now cover the whole of the yolk mass, and on the ventral side the arterioles and venules are very well developed, also covering the whole mass except for the interior of the arterial circle.

The later stages in the development of the arterial system are shown on Pl. XV, figs. 22 to 27.

It is interesting to note the variation in the subsequent development of the so-called arterial circle in this species as compared with that of *Heterodontus japonicus* (Smith, 1942), where the arterial circle eventually becomes very narrow, and finally the right and the left sides coalesce so as to obliterate the circle completely. In the present species, as previously mentioned, there is only a lateral coalescence, the central portion of the circle disintegrating so that there is no coalescence in this region.

Summary.

1. *Poroderma africanum* is an oviparous species of dogfish with a fairly limited range of distribution in South African seas.

2. The male and the female reproductive systems are described.

3. Development of the embryo takes place wholly within a transparent egg capsule and the whole development can readily be observed.

4. The complete embryology from the time of the laying of the capsule until the time of hatching, occupying an incubation time of 164 days, is described.

5. The vitelline circulation is described for the complete incubation time.

6. The embryo at the time of hatching had attained a length of 145 mm.

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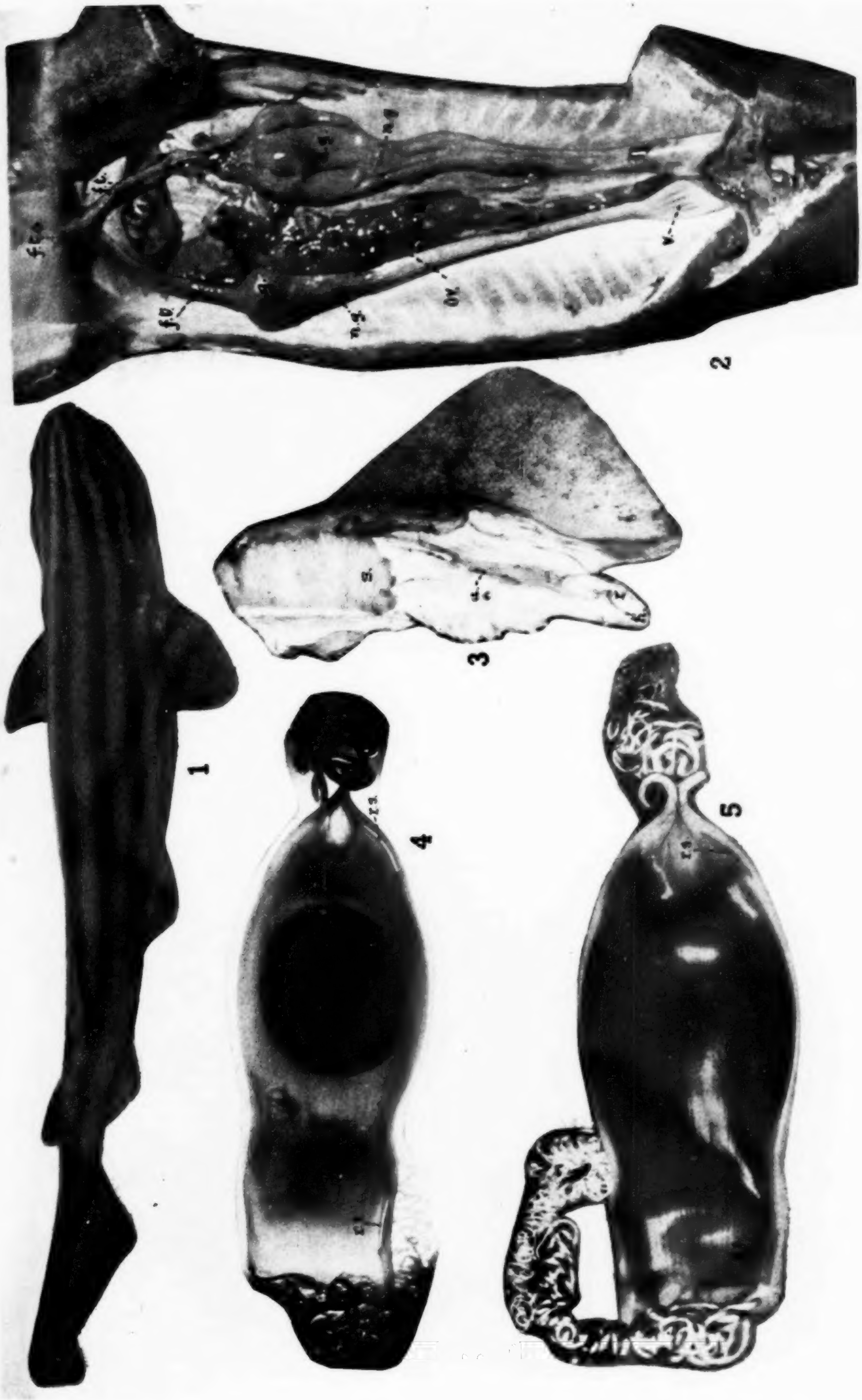

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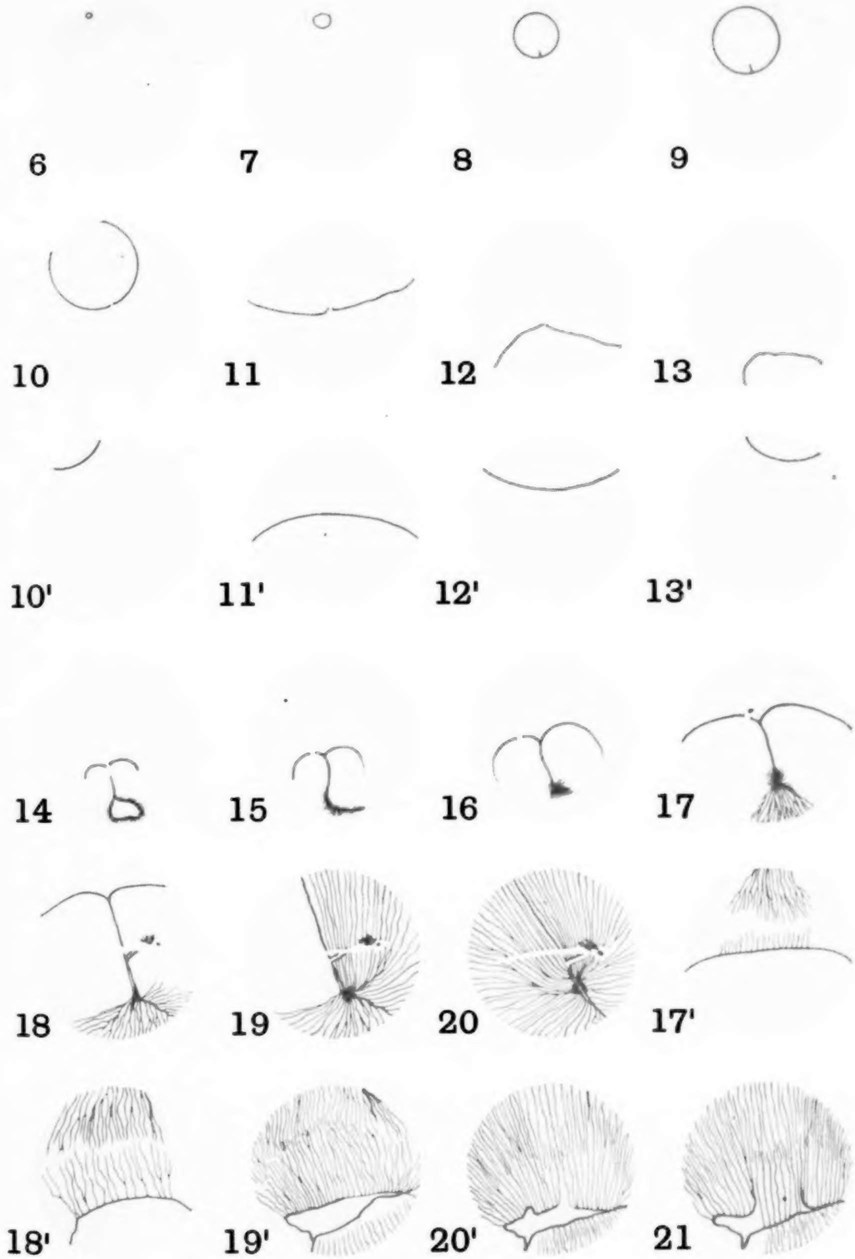

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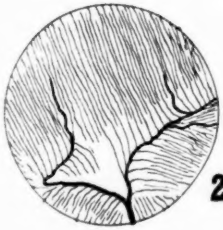

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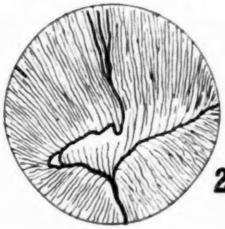

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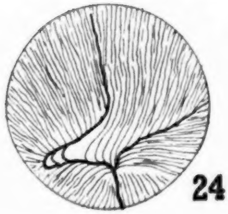

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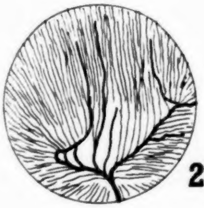

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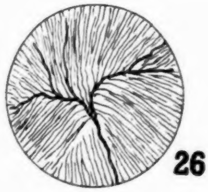

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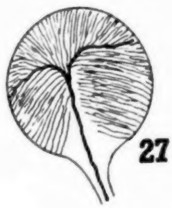

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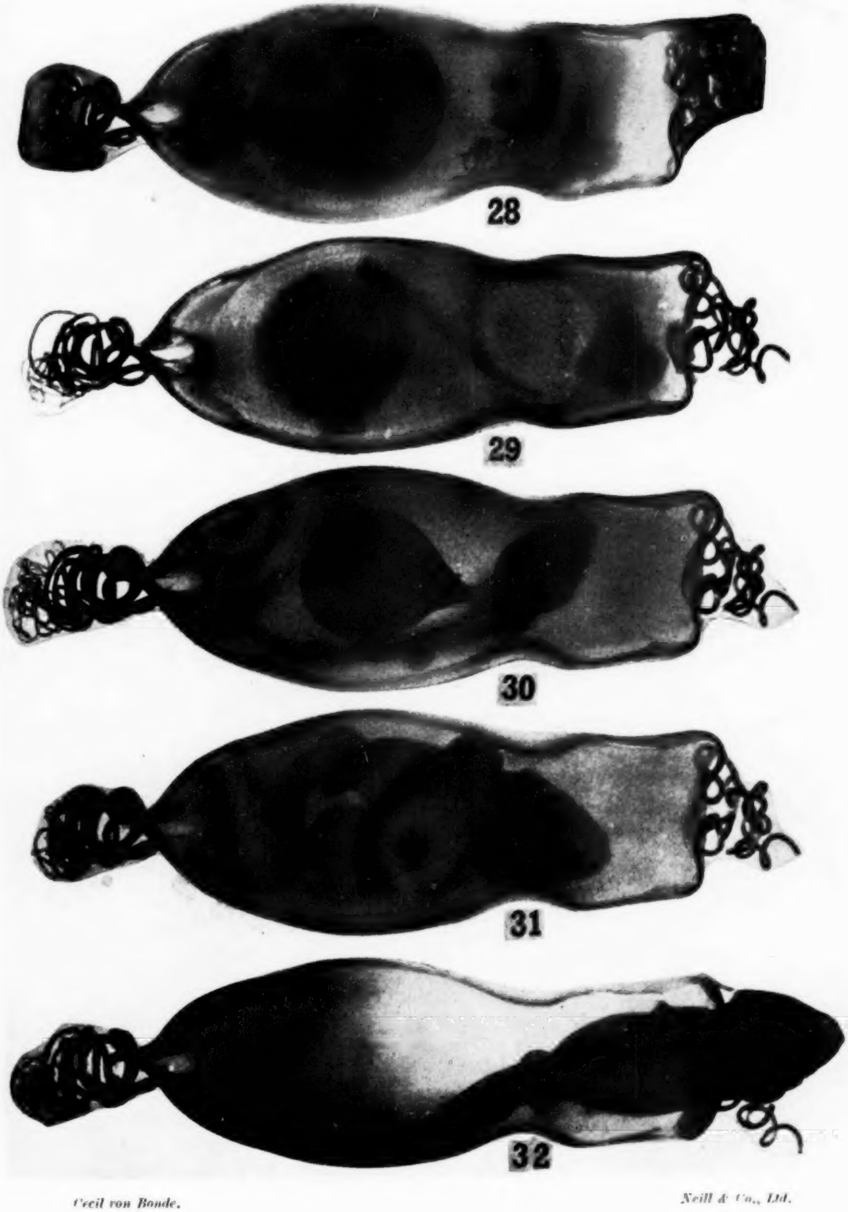

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EXPLANATION OF PLATES.

Plate XIII.

Fig. 1. Dorso-lateral view of *Poroderma africanum*.
Fig. 2. Dissection of a female, showing the reproductive organs. The left oviduct has been opened along its entire length to show the internal structure.
Fig. 3. Clasper of male.
Fig. 4. Photograph of an egg capsule as a transparent object.
Fig. 5. The same as an opaque object.

Plate XIV.

Fig. 6. Dorsal side of the yolk mass at the time of the laying of the capsule, showing the blastoderm.
Fig. 7. The same three days old.
Fig. 8. The same six days old. The embryo has just appeared.
Fig. 9. The same eight days old.
Fig. 10. The same ten days old.
Fig. 10′. Ventral side of same.
Fig. 11. Yolk mass fifteen days old.
Fig. 11′. Ventral side of same.
Fig. 12. Yolk mass eighteen days old.
Fig. 12′. Ventral side of same.
Fig. 13. Yolk mass twenty-one days old.
Fig. 13′. Ventral side of same.
Fig. 14. Yolk mass twenty-four days old, showing yolk blastopore.
Fig. 15. Same twenty-five days old, showing yolk blastopore completely closed.
Fig. 16. Yolk mass twenty-eight days old.
Fig. 17. Yolk mass thirty-one days old.
Fig. 17′. Ventral side of same.
Fig. 18. Yolk mass thirty-five days old.
Fig. 18′. Ventral side of same, showing arterial system.
Fig. 19. Yolk mass thirty-eight days old.
Fig. 19′. Ventral side of same, showing arterial circle.
Fig. 20. Yolk mass forty-two days old.
Fig. 20′. Ventral side of same, showing rupture of arterial circle.
Fig. 21. Ventral side of yolk mass forty-five days old, showing arterial system.

(*Note.*—For convenience the diameter of the yolk mass in each figure is shown the same. In figs. 16, 17, 18 and 19 the umbilical cord should have been placed nearer the head—*cf.* its correct position in fig. 20.)

Plate XV.

Fig. 22. Ventral side of yolk mass fifty-six days old, showing arterial system. Diameter of yolk 30 mm.
Fig. 23. Same sixty days old. Diameter of yolk 30 mm.
Fig. 24. Same sixty-seven days old. Diameter of yolk 28 mm.
Fig. 25. Same eighty-four days old. Diameter of yolk 27 mm.
Fig. 26. Same one hundred and six days old. Diameter of yolk 25 mm.
Fig. 27. Same one hundred and twenty-two days old. Diameter of yolk 21 mm.

PLATE XVI.

Fig. 28. Egg capsule at time of laying, showing yolk mass.
Fig. 29. Egg capsule after 61 days, showing 45-mm. embryo.
Fig. 30. Egg capsule after 107 days, showing 85-mm. embryo.
Fig. 31. Egg capsule after 132 days, showing 136-mm. embryo.
Fig. 32. Egg capsule at time of hatching of the 145-mm. embryo after 164 days.

(All photographs and drawings by Author.)

ABBREVIATIONS.

a. = apopyle.
a.g. = albumen gland.
f.t. = fallopian tube.
f.t.o. = cœlomic orifice of fallopian tubes.
h. = hypopyle.
n.g. = nidimental gland.
ov. = ovary.
r. = rhipidion.
r.s. = respiratory slit.
s. = siphon.
t.m. = transverse membrane of cloaca.
v. = vagina.

ON A NEW GENUS OF FISHES OF THE FAMILY CREEDIIDAE FROM SOUTH AFRICA, WITH REMARKS ON ITS GEOGRAPHICAL DISTRIBUTION.

By L. F. DE BEAUFORT, Zoological Museum of Amsterdam, Netherlands.

(Communicated by C. J. VAN DER HORST.)

(With one Text-figure.)

(Read March 20, 1946.)

In 1898 Ogilby (1) described a remarkable fish from Maroubra Beach, near Sydney, as *Creedia clathrisquamis*, new genus and species, and of uncertain position. In 1903 Waite (5) pointed out that this species is identical with *Hemerocoetes haswelli*, described in 1882 by Ramsay (2) from Port Jackson, and that Ogilby's species therefore has to be called *Creedia haswelli*. In 1913 Tate Regan (3) created the family Creediidae for this genus, and placed it near the Hemerocoetidae, Trichonotidae, and Limnichthyidae in the suborder Trachiniformes. A second genus of this family has been described by Rendahl (4) as *Squamicreedia obtusa* from Cape Jaubert, N.W. Australia.

Up to now no representatives of this family have been found outside the coastal waters of Australia, but among the material collected by Dr. C. J. van der Horst, Professor of Zoology at Witwatersrand University, Johannesburg, and his students on the island Inhaca in the Delagoa Bay, I found three specimens belonging to the Creediidae, and representing a new genus and species, described below.

Through this discovery the range of the family is considerably enlarged. The species seem to be rare, or they may have a mode of life which renders it difficult to collect them; at least they are only known by a few specimens each, and it is possible that they have escaped notice on other coasts.

Hence it is not of much use to speculate at length on the distribution of these fishes, but even with our present scanty knowledge there are some points which ask for our attention.

The three localities where Creediidae have been found are situated inside the limits of the Indo-West Pacific litoral region. There is nothing very remarkable about this fact, for many other families of fishes and other marine animals have the same distribution, but in these last cases the genera

are not geographically isolated as in the Creediidae; on the contrary, generally the genera, and often also the species, are distributed over the whole area. This gives the impression that the distribution of the Creediidae is of another character; it looks as if it is older, and that the three genera, now restricted respectively to East Australia, West Australia, and South Africa, are the relicts of a former much wider distribution. Another remarkable fact is that, so far as our present knowledge goes, the family is confined to the southern part of the Indo-West Pacific region. The nearest relatives of the Creediidae are the Hemerocoetidae, a family which is more antiboreal than tropical, and the question arises if the Creediidae did not originate in the south, perhaps on the coasts of an Antarctic continent, which united Australia and Africa, and spread from there in a northern direction, intruding into the Indo-West Pacific region, but not belonging to its original fauna. The former existence of an Antarctic connection between Australia and Africa is very questionable, and I am not prepared to declare myself in favour of such an hypothesis. We shall have to wait for new finds before we can say something more definite about the distribution of this remarkable family.

Apodocreedia nov. gen.

Body elongate, covered with cycloid scales. Lateral line curved down behind the pectorals, and running along the lower side of body and tail, where its scales are trilobed, the median lobe being much longer than the others, and pointed. Head naked. Mouth protractile, large. Maxillaries slender, but dilated posteriorly, excluded from the bordering of the mouth by the long praemaxillaries, which are finely toothed. The praemaxillaries bear anteriorly a fleshy projection in front of the mouth. Vomer and palatines without teeth. Eyes close together. Gill membranes free from each other and from isthmus. Seven branchiostegals. Dorsal and anal long, the former beginning somewhat in advance of the latter, both fins consisting of articulated, unforked rays. Caudal rounded. Pectorals low down. Ventrals wanting.

This new genus differs from *Creedia* in the absence of ventrals, in the much longer dorsal, and in having teeth on the praemaxillaries. In the long dorsal it agrees with *Squamicreedia*, but the last-named genus has the head scaly, and ventrals are present.

Type of the genus: *Apodocreedia vanderhorsti.*

Apodocreedia vanderhorsti nov. spec.

D. 33–38. A. 29–31. P. 12. Ll. 57–61. Ltr. $\frac{8}{1}$.

Height 13·5–16, 14–17 in length with caudal. Head 5·5–5·7, 6 in length with caudal. Eye 7·5–10, 1·5–2 in snout. Eyes close together, the inter-

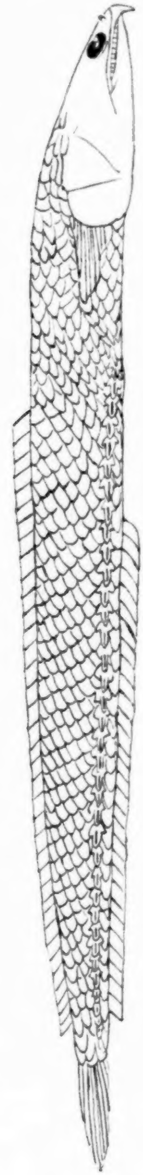

FIG. 1. *Apodocreedia vanderhorsti*, twice natural size.

orbital space being less than their diameter. Mouth very large, maxillary reaching far behind eye. Minute teeth in two rows along the inner border of the praemaxillaries. Lower jaw with 13–20 slender, pointed, somewhat curved teeth. Opercular bones thin, translucent, with smooth borders. Scales beginning on nape above hind border of praeoperculum. Hind border of the scales not rounded, but pointed, the angle formed by this point being acute on nape and on lower side, and about 90° in the others. Eleven anterior scales of the lateral line also with the hind border acutely pointed, the twelfth, which is the first of the straight course of the lateral line after the bent downwards, trilobed, the median lobe of which is much longer than the others. Following scales of the lateral line as the twelfth. 20–23 scales before dorsal, the origin of which is twice nearer tip of snout than end of caudal. Dorsal low, its height less than half height of body, the post-median rays somewhat longer than the others. Origin of anal below sixth ray of dorsal, two scales behind anus. Anal similar to dorsal, but shorter, both fins ending opposite to each other, at a short distance from base of caudal. Rays of caudal forked, the fin rounded. Pectorals somewhat pointed, their length equal to length of upper jaw, their rays articulated but undivided. Colour of preserved specimens light yellowish, scales of back, of middle of sides, and along base of anal with more or less dusky hind borders, forming three indistinct longitudinal bands on body and tail.

Length of three specimens examined 70, 76·5, and 82 mm.

Habitat: Inhaca Island in Delagoa Bay, S. Africa.

Note.—After this paper was read and in print Professor van der Horst informed me that 51 specimens in total were found in wet sand during low tide, at the northern point of Inhaca, February 1938.

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CAPE CHEMICAL SOCIETY

MARLOTH MEMORIAL

A STATISTICALLY DESIGNED EXPERIMENT TO TEST THE EFFECTS OF BURNING ON A SCLEROPHYLL SCRUB COMMUNITY. I. PRELIMINARY ACCOUNT.

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(With Plates XVII–XXIV and one Text-figure.)

(Read April 17, 1946.)

Introduction.

Few intensive ecological field investigations have been conducted in the sclerophyll scrub vegetation of the south-western Cape. The effects of fire were studied by Adamson (1927, 1931, and 1935) and Levyns (1924, 1929, and 1935) in the western parts. In the indigenous forest region at Knysna, Phillips (1931) and Laughton (1937) have made observations. All these investigations were descriptive. They were not designed to provide a valid estimate of error, and could not be expected to prove what the effects of treatments on the vegetation would be. They were careful accounts of the vegetation and its development after treatment, and they added considerably to the accumulated observations of the constitution of the vegetation and the effects of treatment on it. If it is desired to investigate further and to *prove* the differential effects of various treatments, statistically planned experiments are needed. The experiment to test the effects of burning in different months, which is being conducted at the Jonkershoek Forest Influences Research Station, Stellenbosch, and is described in this paper, constitutes a first attempt to apply statistical design to a field investigation in the exceedingly rich and varied sclerophyll scrub.

Statistical methods in plant ecology have been applied to the classification of communities, the analysis of vegetation, sampling studies, and the design and interpretation of field experiments. The classification of vegetation on a statistical basis has been unsuccessful so far. Blackman (1935) and Ashby (1935, 1936) have pointed out the shortcomings of the attempts made by du Rietz and others to use statistical or quantitative methods in the classification of plant communities. Ashby (1936) came to the conclusion that "the classification of vegetation still rests upon personal judgment and intuition which cannot be replaced by any mechanical

quantitative method." He described statistical methods as "worthless as a basis for classification." This appears to be a rather sweeping condemnation. It is true that no satisfactory quantitative criterion has thus far been evolved, but the possibility should not be excluded. Classification of vegetation is so widely based on *dominance*, the personal and intuitive judgment of which is so problematic, that it would be an important advance if the concept could be fully or even partially defined in quantitative terms.

The application of statistical methods to the analyses of vegetation and sampling has been more successful. This has been demonstrated by Blackman (1935), Ashby (1935, 1936), Clapham (1936), Pidgeon and Ashby (1940), Pechanec and Stewart (1941), Horton (1941), and others. The purpose of analytical studies is to provide clear, precise, objective information about the internal structure of plant communities. The subjective demarcation of communities will determine the extent of the variation which will be included and observed within them, but will not affect the validity of the analysis. Statistics merely provide a "tool" for vegetation studies, and not a system of concepts on which vegetation studies can be based. Studies of the distributions of individual species within the community have proved particularly fruitful. Analytical studies such as these, and preliminary sampling carried out in plant communities before surveys or experiments are undertaken, greatly increase the reliability of conclusions drawn. This field of research has thus far escaped the attention of ecologists in South Africa.

Ecological field experiments are likely to be conducted on an increasing scale in South Africa, and modern statistical designs and interpretations should be applied to such experiments in order that the maximum amount of reliable information may be extracted from the observational data. Modern experimental technique has become standardized in the last fifteen years as a result of the work of the school of statisticians led by Professor R. A. Fisher (1936, 1937). The improved methods were first applied to agricultural field experiments and they are generally used in agricultural research in South Africa. Their advantages have, however, apparently not yet been fully appreciated by South African plant ecologists. The new designs and interpretations of experiments provide reduction in experimental error and valid estimate of error. These advantages are attained through replicating treatments and applying them at random. Without these refinements no field experiments can be said to conform to modern standards. Their use has, in fact, converted this branch of research to exact science compared with its previous casual nature.

A number of expositions of this subject, dealing with the various experimental designs and technique, have been published. Elementary treatments, intended for workers who have no advanced knowledge of

mathematics, are given by Paterson (1939), Saunders (1939), Goulden (1939), Snedecor (1940), Wishart (1940), and Mather (1943). Such works provide the details for the application of statistical methods. The description in this paper of an experiment being conducted at Jonkershoek will illustrate some of the advantages of applying statistical methods to the field investigation of an ecological problem.

There is a fundamental difference in the use of quadrats in descriptive and statistical ecology. In descriptive ecology the selection is purely subjective. Weaver and Clements (1938) state that "A number of quadrats, located with care in places that appear to be different upon careful scrutiny, will reveal the entire range of structure. The quadrat, like any other method, must be used with discrimination, and it should rarely be located at random, except in pure stands of a single species." The descriptive ecologist thus uses the quadrat to give an exact picture of a small portion of the vegetation which he has selected for describing. Each quadrat is intended to reflect the composition and structure of a single pre-selected community or community variation. The more successful the subjective selection of the quadrat the truer will be the description of the vegetation, which will be based on the observations made on the quadrat. Personal judgment of variation in the vegetation before observations are made plays the dominant part. Descriptive ecologists are often satisfied with only one quadrat in a community that appears uniform to them. Clearly, such descriptions of vegetation based on one or a few quadrats, however carefully sited, must often be very strongly biased and unreliable. Great variation found by the intensive analysis—described in this paper—of a relatively small, apparently uniform, community in Jonkershoek shows that a number of quadrats can never "reveal the entire range of structure" in vegetation as variable as the sclerophyll scrub. The fact that sampling at random and statistical analysis of observations entails more field work and lengthy computations is irrelevant if the object—an exact account of the vegetation—cannot be attained in another way.

The approach, where statistics are applied in the analytical investigation of vegetation, is entirely objective and conclusions are free from bias. The statistical ecologist uses the quadrat as a tool to analyse variation in vegetation. The single quadrat observation, whether it is of height, cover, density, or some other feature, becomes a single value of the variate being investigated, and the statistical ecologist is concerned with the variation in the feature selected for study as reflected by observations on a number of random quadrats. It is a prerequisite of statistical methods that these quadrats *must be located at random*. The statistical ecologist derives a true picture of the vegetation he is investigating from all quadrats taken together. These quadrats constitute a series of replicated random samples from the

community. According to the extent of the variation observed by him he is able to judge whether the account of the vegetation, which he can base on his observations, is reliable or not. The descriptive ecologist relying on personal judgment and intuition has no criterion for testing the reliability of his accounts of vegetation.

The experiment described here not only demonstrates the use of statistics, but also provides a detailed account of a particular sclerophyll scrub community, and yields some preliminary results of the differential effects of burning in successive summer and autumn months.

Design of Experiment.

The eight treatments selected for testing were burning on the fifteenth day of each of the following months in the year 1945: January to April and September to December. In order to obtain a clean burn on such small areas it was necessary to scatter some dried material, which had been removed by hoeing from adjacent surrounds. This probably caused the fire to be somewhat hotter and fiercer than would have been the case had a natural burn occurred. While some years must elapse before final conclusions on the effects of these treatments can be drawn, the plan of the experiment, the analysis of vegetation on the experimental site, and the preliminary effects of burning are described here.

The lay-out of the experiment is in randomised blocks as follows (see Pl. XVII, fig. 1):—

	1.		2.		3.		4.		5.	
SLOPE ↓	F	G	D	E	D	F	B	G	D	B
	B	H	B	F	H	E	C	F	E	A
	C	E	C	G	B	C	H	A	C	F
	A	D	H	A	A	G	D	E	H	G

The eight treatments, A to H, were allotted at random within each of the five blocks.

The experimental quadrats were four square metres and were separated by surrounds of two metres wide. This size of quadrat is also recommended by Weaver and Clements (1938) for descriptive studies in the somewhat similar Chaparral vegetation of California. The actual total area on which observations were made was, therefore, 160 square metres (about ·04 acre). The area of the experiment was 756 square metres (about ·19 acre), if a two-metre-wide surround on the perimeter is allowed.

For certain purposes the size of the quadrats is rather small. Thus, for example, seeding from unburnt quadrats on to those that have been burnt will occur, and it will not be possible to judge the survival of plants after fire in the form of seed. To investigate this question such large areas would be required, however, that they could not be included within the scope of an experiment such as is being considered here. The quadrats may be somewhat too small to give a true sample of the very variable community. They may also be unduly influenced by adjacent treatments, because of their small size and rather narrow surrounds.

Increase in quadrat size and width of surround have definite disadvantages. It entails a decrease in the number of replications which can be accommodated on the area, and thus reduces accuracy of the experiment. In the present instance it could only be attained satisfactorily if the number of treatments being tested are simultaneously reduced. This expedient may have to be adopted if increase in the size of plots proves to be essential.

In the final analyses of observations the total variance * (Fisher, 1936, 1937) will be divided into variance due to treatment, blocks, and error. The last portion will be due to uncontrollable variation of the experimental material in the quadrats. The advantage of the arrangement in blocks is that a portion of uncontrollable variation can be assigned to variation between blocks affecting all treatments equally, and excluded from the estimation of experimental error. Statistical tests will be applied to determine whether the treatment variance may be accepted as significantly higher than that due to error.

The experimental area is situated on a slope of 20° 45′ with a north-eastern aspect. There are no rock outcrops on the area. The underlying geological formation is granite, but the soil has a strong admixture of siliceous material from Table Mountain Sandstone precipices higher up the mountain. The site is well drained, becomes very dry in summer, and, due to the aspect, it is also very hot. These features of the site cause the vegetation to show rather poor vigour; growth is slow and the resultant community is low and rather open. The humus content of the soil is poor.

The vegetation before the experiment was established was sclerophyll scrub regrowth, which was six years old after fire in November 1944. The area was selected with care for the apparent uniformity of the vegetation, which was in fact probably no more variable than that on any other area of equal size on the Jonkershoek Forest Reserve. The tall whip-like shrub

* The most effective measure of variability is the *standard deviation*. The *variance* is the square of the *standard deviation*. Fisher has shown that there are considerable advantages to be derived from the use of this statistic in the statistical interpretation of data. He has developed the appropriate Method of Analysis of Variance.

Anthospermum aethiopicum L., which was most abundant and conspicuous, should probably be looked upon as dominant, but this plant provides slight cover, and there were a number of sub- or co-dominants lower in height (see Pl. XVII, fig. 2). Those which were most conspicuous and provided most cover were *Leucadendron adscendens* R.Br., *Stoebe plumosa* Thunb., *S. capitata* Berg., *Montinia acris* L.f., *Themeda triandra* Forsk., *Danthonia stricta* Schrad., and some other shrubby species. Altogether 53 species were recognised in January 1945, but some grasses not in flower as well as a few small herbs and shrubs could not then be identified.

Analysis of Vegetation before Treatment.

In a preliminary study of the vegetation on the area, the heights of prominent plants of the species *Anthospermum aethiopicum* L., *Leucadendron adscendens* R.Br., *Montinia acris* L.f., and *Stoebe plumosa* Thunb. were measured, ocular estimates of cover percentages were made on all quadrats, and the numbers of plants per species on all quadrats were recorded. These observations are summarised in Table I.

Table I.

Summary of Enumerations in January 1945.

Variable Observed.	Means of Sets of Quadrats selected for different Treatments.								General Mean.
	A.	B.	C.	D.	E.	F.	G.	H.	
Total number of plants	265·0	205·4	225·2	211·2	236·6	189·0	214·2	228·8	222·0
Number of species	25·6	26·2	26·6	24·6	28·2	26·2	26·8	24·0	26·0
Cover percentage	74	73	75	69	69	71	83	74	73·5
Number of *Anthospermum*	74·0	39·8	51·0	49·4	47·6	38·6	50·0	44·0	49·3
Number of prominent *Anthospermum*	19·0	28·2	28·0	30·0	22·4	22·1	29·2	27·6	26·1
Height of prominent *Anthospermum* plants—inches	43·3	39·0	41·3	39·9	40·7	35·3	41·4	40·3	40·2
Height of Sub-dominants—inches	23·5	21·1	19·7	19·6	20·4	20·2	22·2	19·2	20·8
Number of a *Ficinia*	55·6	39·2	41·6	37·0	41·6	30·6	55·4	41·6	42·8
Number of grass plants	26·8	12·8	16·4	17·0	21·0	21·2	12·2	14·8	17·8

All Species Collectively.

The total number of plants of all species on the area was 8879, so that the mean number per quadrat was 222. The number of plants per quadrat

ranged from 113 to 314. To test uniformity of the area the quadrats may be combined in any way desired before treatments are applied. In the study of total number of plants of all species, an analysis of variance was carried out to test whether the portions of variance due to differences between row means, column means, means of sets of five quadrats pre-selected for different treatments, and block means were significant. In most cases the error variance was of about the same magnitude as the variance from other sources, so that the area was clearly uniform as far as the total number of plants per quadrat—the density of plants—was concerned.

The coefficient of variation (v), or standard error of a single estimation expressed as a percentage of the mean, after variance due to blocks and treatment had been excluded, was 20·7 per cent. for quadrat totals. The standard error (S.E.) of the mean of five quadrats was, therefore, 9·25 per cent., which is (v) divided by the square root of 5. If a difference between treatment means is accepted as significant when the probability of its occurrence due to chance is less than 1 in 20, then it may be deduced from the above observations * that a difference of about 26·8 per cent. in treatment means will have to be observed to obtain a positive result. The difference required is large, and in order to determine the effects of the burning treatments on total number of plants per quadrat it may be necessary to reduce the experimental error further by introducing more replications of treatments. Better results will also probably be obtained if the number of plants after treatment is expressed as a percentage of number of plants before treatment for each quadrat, and these figures of the relative changes in density of plants are used in analyses.

At the time of the mid-summer enumeration in January 1945 many geophytes and therophytes were not in evidence, and the list was restricted to herbs and shrubs. Lichens, mosses, and other lower plants were inconspicuous or absent on the areas examined. The five species with highest mean densities—*Anthospermum aethiopicum* L., *Ficinia capillaris* Nees ex Levyns, *Centella bupleurifolia* (Rich.) Adamson, *Stoebe capitata* Berg., *Montinia acris* L.f.—made up 60 per cent. of the total number of plants on the area. Two of these, the *Ficinia* and the *Centella*, played subsidiary rôles in the community. The first 24 species included all those that were conspicuous on the area, and they constituted 90 per cent. of the total number of plants. The last 25 species, in order of density, constituted only 5 per cent. of the total number of plants.

In text-fig. 3 the increase in the number of species recorded with increase in the number of four square-metre quadrats selected is shown. A smooth

* To accomplish this, use was made of a table giving the distribution of t (Fisher, 1936).

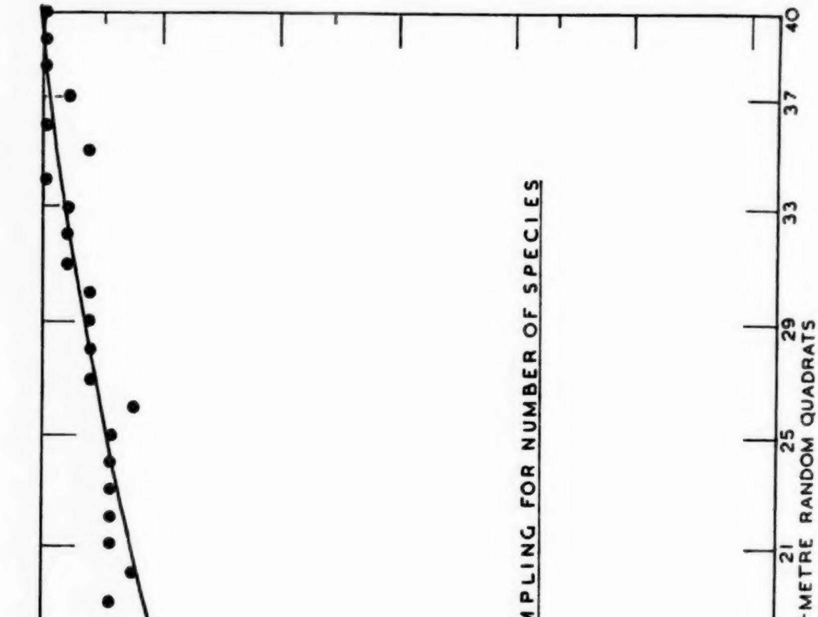

FIG. 3. RANDOM SAMPLING FOR NUMBER OF SPECIES

curve of the form $Y = a + b \log X$ was fitted to the data. From the graph it appears that one quadrat selected at random will include only about 54 per cent. of the species on the average (the mean number of species per quadrat computed from all 40 quadrats was actually 26 or 50 per cent.). The number increases rapidly at first, so that five quadrats will include 75 per cent., but the curve then flattens so that 17 quadrats selected at random are needed before 90 per cent. of all species are included, and 35 to 40 are needed to include all species on the area. In this investigation of the effect of burning on the vegetation we are, however, concerned mainly with the more prominent species, and they are fairly evenly distributed. Two —*Anthospermum aethiopicum* L. and the small *Ficinia capillaris* Nees ex Levyns—occurred on all quadrats. Of the first 24 species in order of density only two did not occur on all sets of five quadrats pre-selected for various treatments. One was the grass *Hyparrhenia hirta*, Stapf., which was very irregularly distributed; the other was *Helichrysum cymosum*, Less., which came 23rd in order of density.

To determine the effects of the different burning treatments on the number of species in evidence at a given time, the total numbers of species recorded per quadrat, irrespective of what these are, may be analysed. In January 1945 the numbers of species per quadrat were very closely grouped about the mean number, 26, showing that the area was uniform in this respect. The coefficient of variation was only 13·4 per cent., giving a standard error for the mean of five replications of 6 per cent. It will be possible to examine the variation in the number of plants in flower at a given time, and also other features in the same way.

*The Cover.**

The mean percentage cover of all quadrats was 73·5. Analysis of variance showed that the variation over the area was uniform, because no significant difference between row, column, block means, and between means of sets of quadrats pre-selected for various treatments, were found. The coefficient of variation for quadrat totals was 15·5 per cent., and the error of the mean of five plots was therefore 6·9 per cent. A significant difference between the means of two sets of five quadrats would in this case have to be greater than about 20 per cent. if a probability of 5 per cent. is required. This figure is again high, but the position may be improved if relative changes in cover are used in final comparisons of treatments. Other refinements that may have to be resorted to are increased replication of treatments, and improvements in the technique of estimating cover.

* Cover was determined by imagining the twigs and foliage of all plants projected on to the ground and estimating the relative area covered.

The Dominant, Anthospermum aethiopicum *L.*

Analyses similar to those carried out for total number of plants per quadrat and cover were done for the number of prominent plants per quadrat of *Anthospermum aethiopicum* L., total number of plants per quadrat of this species, and the mean heights of prominent plants. The species was represented on all quadrats and made up the largest portion—22·2 per cent.—of the total number of plants on the area. The plants appeared to fall into two fairly distinct groups: tall prominent plants, probably grown from the first seedlings which developed after the fire six years previously, and smaller seedlings, probably a second generation developing from seeds dropped by the more prominent plants.

The heights of prominent plants were measured in inches and the mean heights for each quadrat computed. The general mean height of prominent plants computed from the unweighted means of all quadrats was 40·16 inches. Analysis of variance by rows and columns of quadrats showed that a highly significant portion of variance was due to differences between row means, and that this could be ascribed to a significant increase in height of the prominent plants down the slope. The successive row means down the slope were 34·6, 36·6, 43·0, and 46·5 inches. Further analyses showed that the portion of variance due to differences in means of sets of quadrats pre-selected for different treatments was quite insignificant. The sets must therefore be equally affected by the systematic variation associated with slope. To demonstrate the effects of treatment it again appeared that it would be desirable to analyse the relative changes in the heights of prominent plants rather than the heights reached after burning. This may also be accepted as advisable for all other features observed and selected for analysis, because the dispersions of readings about the general means—as reflected by relatively large values of standard deviations—is considerable in all cases. The five replications may, therefore, be too few to reduce the standard errors of mean readings of treatments sufficiently to show significant differences, unless the differences are very large.

The total numbers of plants of the dominant species on individual quadrats varied considerably. The range was from 20 to 147. The general mean number—the mean density—was 49·3, with the large coefficient of variation of 42·35 per cent. Considerable differences in numbers of individuals may, however, occur after treatment because a large number of seedlings may develop on ground cleared by burning. These will probably in time become reduced in consequence of competition, so that eventually the numbers may not differ significantly from those observed before treatment.

The total number of plants of the dominant species per quadrat showed

an increase down the slope, but this was not highly significant as in the case of the heights of prominent plants. Considering the prominent plants of this species alone, we find that the trend is reversed and that there is a highly significant increase in number higher up the slope. For the first even-aged generation of this species the stand therefore becomes denser as the site becomes poorer—drier—up the slope. This condition has frequently been observed in even-aged forest stands where better sites usually carry stands composed of fewer, larger trees than poorer sites. The second seedling generation of *Anthospermum aethiopicum* L. was, however, apparently able to develop better on the moister sites lower down the slope.

In no case were the means of sets of treatment quadrats sufficiently differentiated to contribute significant portions of variance.

The Sub-Dominants.

The most conspicuous sub-dominant species, *Leucadendron adscendens* R.Br., *Stoebe plumosa* Thunb., and *Montinia acris* L.f., differ from the dominant, *Anthospermum aethiopicum* L., in that they are species that sprout from root-stocks after fire, while the dominant species re-develops from seed in most cases. In an enumeration of number of individuals on the area, these species come relatively low down on the list—*Montinia*, third, with 4·3 per cent.; *Stoebe*, thirteenth, with 1·7 per cent.; *Leucadendron*, eighteenth, with 1·2 per cent.—because each stool was counted as one plant. Such a stool, however, often had many shoots, in the case of *Leucadendron adscendens* R.Br. 20–30 or more, and provided considerable cover. These species are, therefore, conspicuous in the community, and to this they owe their selection as sub-dominants in the accepted ecological sense of the term. There appeared to be few seedlings of the *Leucadendron* and the *Stoebe*, but a fair number of the *Montinia*.

In order to investigate the height growth of these species the tallest shoot on each stool was measured. An analysis of the mean quadrat heights of the three species taken together showed a highly significant increase in height down the slope, as in the case of the dominant species, but this systematic variation did not favour any of the sets of quadrats selected for different treatments.

A Ficinia *and Grass Species.*

One of the most interesting of the subsidiary species appeared to be the relatively small *Ficinia capillaris* Nees ex Levyns. It was represented on all plots, and contributed almost as large a proportion—19·3 per cent.—of the total number of plants on the area as the dominant species—22·2 per cent. It appeared to be in a retrogressive state, but it may at an

earlier stage in the succession have played a more important rôle in the community. The dispersion over the area appeared to be similar to that of the dominant. This is shown by the close agreement of the mean densities—*Anthospermum*, 49·3; *Ficinia*, 42·8—and coefficients of variation of quadrat totals about the means—*Anthospermum*, 42·35 per cent.; *Ficinia*, 38·81 per cent. Like the dominant species, the *Ficinia* also showed a significant increase in number of plants per quadrat down the slope.

The perennial grasses constituted 8 per cent. of the total number of plants in the community. The mean density was 17·8, but the distribution was very irregular. The quadrat totals showed a range from zero to 51. The coefficient of variation of quadrat totals about their means was 77·6 per cent. Treatments would, under these circumstances, have to cause a difference of over 100 per cent. before they could be accepted as significant with a probability of ·05. Increase in the quadrat size or increase in the number of replications of treatment is probably required if the effect of burning on the number of perennial grass plants is to be satisfactorily demonstrated. Casual observations of other features, such as the sprouting of grasses, their regrowth from seed, will, however, give valuable indications of the effects of treatments.

These analyses before the application of treatments have given a clear picture of the natural variation in the vegetation, so that the possibility of biased results is reduced. The valid estimates of experimental errors based on observations of the variability of the vegetation have indicated, in advance, the probable sensitiveness of the experiment. In consequence of the differential burning treatments the vegetation will, after six years' regrowth, again approach the observed conditions or deviate from them. The preliminary examination of the material has given some idea of the magnitude of the differences that would have to develop before they could be accepted as significant. In this way a definite standard for judging the reliability of results has been set in advance.

The most striking feature of the apparently uniform community in which the experiment has been laid out, disclosed by the preliminary analyses, is its extreme variability. The futility of attempting to describe such a community with the aid of a few subjectively located quadrats, however carefully they are sited, has been conclusively demonstrated. Quadrat studies in this type of vegetation will clearly present far greater practical difficulties than similar studies in, for example, the more uniform grass communities of certain parts of the summer rainfall regions of South Africa.

The analyses have also shown that the variations in the vegetation do not favour any one of the sets of quadrats pre-selected for different treatments, so that final results are not likely to be biased by site variations on the experimental area. The variability of the material does, however, establish the need for finding considerable differences in the effects of various treatments before these may be accepted as real. This appears to be the chief weakness of the experiment at present, and it may be necessary to design future experiments with the particular object of overcoming this disability.

Preliminary Results of Burning.

Burning in January, February, March, and April 1945 made it possible to observe the effects of these treatments on the redevelopment of the vegetation during the winter and spring. Some observations of the effects of burning treatments on soil moisture and organic substances in the soil were made, and it was also possible to compare the burnt quadrats with unburnt ones and to observe the effects on the vegetation due to seasonal changes.

The immediate effect of burning was the complete destruction of all living parts of plants above the ground. The dead, charred stems of woody shrubs remained, and the ground was covered with a layer of grey ash. This condition is illustrated in Pl. XVIII, fig. 4. After a few days if wind had occurred, which was usually the case, all the ash was blown away and the soil surface was exposed. On the experimental site the soil surface was a sandy loam, with a fair number of pebbles derived from granite and Table Mountain Sandstone beds. There appeared to be no life left. After about a week grass tufts began to show young green shoots, and after about three weeks sprouts from the root-stocks of *Montinia acris* L., *Stoebe plumosa* Thunb., *Leucadendron adscendens* R.Br., and other sprouting species appeared. This condition is illustrated in Pl. XVIII, fig. 5, and Pl. XXI, fig. 12.

Sprouting continued as shown in figs. 6 to 10, but there were few other changes until the winter rains began. Casual observations on other areas have led to the conclusion that growth would have been accelerated on the quadrats burnt in mid-summer had more rain fallen after burning. Exceptionally dry conditions prevailed in the season when the treatments were being applied. Winter rains set in late, near the end of April, and in the period 15th January to the beginning of the rains only ·57 inch was received (recorded by gauge No. 7, Jonkershoek). The period 15th January to 17th March was almost completely dry, and only ·03 of an inch was recorded. The growth shown in Pl. XIX, fig. 6, and Pl. XX, fig. 9, therefore occurred in spite of unfavourable dry conditions, and was dependent entirely on moisture already in the soil. After the rains began, sprouting was

accelerated (though it was later again retarded by continuous cold wet weather), seeds began to germinate and geophytes began to develop foliage, until the conditions recorded at the mid-winter enumerations were established (see Pl. XXI, fig. 10, and Pls. XXII to XXIV, figs. 13 to 17). The photographs reproduced in Pl. XXIII, fig. 14 to Pl. XXIV, fig. 17, all taken on the 27th of June 1945, give an impression of the appearance of quadrats burnt on the 15th of January, February, March, and April respectively. Quadrats burnt in January and February are clearly much more advanced than those burnt in March and April, thus showing that considerable growth occurred in the rainless period before the winter. Rycroft (1946) has found that surface run-off in winter is significantly accelerated if the vegetation is burnt off in late autumn and the soil left bare, as shown in Pl. XXIV, figs. 16 and 17.

In spite of the smallness of the quadrats, the impression was gained that most of the seeds which germinated in winter must have remained on the ground after burning and that they were not derived from adjacent unburnt areas.

Some sprouting species flowered before the winter on burnt plots. In winter many *Oxalis* flowers appeared (see Pl. XXI, fig. 11), and from then onwards, continuing into the spring, more sprouting species, many monocotyledonous geophytes and therophytes came into flower.

The soil surface on unburnt quadrats appeared green in winter due to mosses and algae, but this was not so on burnt quadrats.

Moisture and Organic Substances in the Soil.

Observations in Chaparral vegetation in California (Bauer, 1936; Sampson, 1944) have indicated that the moisture, below 6 to 9 inches of surface soil, becomes less depleted during the dry season after the vegetation has been removed by burning. This is considered to be due to the cessation of transpiration, which is practically the only process by which moisture is withdrawn from the deeper soil layers. Viehmeyer and Johnston (1944) consider the fact that the loss of water from soils is essentially through plant transpiration and not evaporation from the surface of particular importance. They suggest that "denudation of watersheds would then seem to offer a means for increasing water supplies."

The application of burning treatments in the Jonkershoek experiment appeared to offer an opportunity for testing the American findings in the Cape sclerophyll vegetation. Soil samples were therefore taken from two sets of five quadrats. One set had been burnt on the 15th of January 1945, 44 days before sampling, a period during which no rain was recorded. The other set had not been burnt for over six years. Samples were taken

to include the upper 6 inches of soil and at 2 feet below the soil surface. Two samples were taken at each depth for each quadrat, and the means computed from these were analysed to determine the effect of burning. Burnt and unburnt quadrats were in five pairs, one pair from each block. "Student's" method of paired differences (Fisher, 1937) was used to interpret the results.

Soil moisture in the top 6 inches of soil showed slight irregular differences which were statistically quite insignificant. At 2 feet below the surface, soil moisture in the burnt quadrats was higher for all five pairs of observations. The differences were, however, very variable, and the application of the t test showed that the result could *not* be accepted as significant at a probability of ·05. The observations therefore merely provide an indication that the American results probably also apply here, but further

TABLE II.

SUMMARY OF ENUMERATIONS IN JUNE–JULY, AND SEPTEMBER 1945.

Variable Observed.	Means of Sets of Quadrats selected for different Treatments.								General Mean.
	A.	B.	C.	D.	E.	F.	G.	H.	
JUNE–JULY.									
Total number of plants .	1444	1223	936	1095	1211	1183	1254	1265	1201
Heights of *Stoebe*, *Leucadendron*, and *Montinia* spp.—inches . . .	5·5	3·9	2·9	1·9	17·5	17·1	19·7	16·5	10·62 XX
Number of *Oxalis* rosettes .	480	415	324	320	464	589	505	434	441
Number of *Oxalis* in flower	8·2	7·2	4·2	4·2	7·6	6·4	6·2	8·2	6·53
Number of grass plants .	56	27	30	36	59	54	32	44	42·2
Number of monocotyledenous geophytes . .	114	68	51	80	67	79	98	59	77·0
Number of various seedlings	439	335	245	378	394	276	369	491	365·9
SEPTEMBER.									
Number of *Oxalis* flowers .	51	29	42	31	2	3	8	3	21·1 XX
Number of other plants in flower	13	10	11	8	46	48	43	49	28·5 XX
Number of *Babiana* in flower	3	1	1	2	..	2	1	1	1·7
Number of grasses in flower	·4	0	·2	0	13·6	16·4	20·6	17·0	8·5 XX

Remarks.—*a.* Plots A–D were burnt on 15th January, February, March, and April 1945 respectively. E-plots were burnt on 15th September 1945 before *Babiana* flowers were counted.

b. Monocotyledenous geophytes and the various seedlings were not present in January 1945, and were not then recorded.

c. XX indicates highly significant variance due to differences in treatment.

d. *Anthospermum* could not be recognised on burnt plots, though many very small seedlings were no doubt present.

investigations are required to establish this definitely. In such further investigations it would be advisable to use larger quadrats to minimise the chances of moisture seeping into the areas from outside. The period of denudation should also be lengthened so that the treatment may have greater effect, and more samples should be taken to increase the accuracy of the estimations. This example illustrates admirably how statistical treatment provides a criterion for judging the reliability of an experimental result.

A similar analysis was done of estimations of the ignition loss in weight from the 6 inches of surface soil. The differences in loss between burnt and unburnt quadrats were slight, irregular, and quite insignificant.

From the investigation the tentative general conclusion may therefore be drawn that burning had no *immediate* adverse effect on soil moisture or on organic material in the surface soil layers. Further studies are required to check this deduction.

Number of Plants of all Species.

An examination of the experimental area on the 15th of February showed that grass tufts on the A-quadrats, burnt one month previously, were sprouting, and that occasional root-stocks of *Leucadendron adscendens* R.Br., *Montinia acris* L.f., and *Stoebe plumosa* Thunb. were showing signs of life. No enumeration was carried out. On the 15th of March, when the C-quadrats were burnt, an enumeration of plants on the A- and B-quadrats was carried out. The B-quadrats showed very little development, and only 12 sprouting plants were observed on the set of five quadrats. These were: grasses, 4; *Leucadendron*, 5; *Royena glabra* L., 1; *Stoebe*, 1; and one small unknown plant. On the five A-quadrats, burnt two months previously, the following species were sprouting:—

Aspalathus divaricatus Thunb.	10
Borbonia parviflora Lam.	1
Diosma vulgaris Schl.	2
Hibiscus aethiopicus L.	2
Leucadendron adscendens R.Br.	13
Montinia acris L.f.	4
Phylica spicata L.f.	2
Protea acaulis Thunb.	1
Royena glabra L.	1
Stoebe species	4
Grasses	24
Total number of plants	64

One-third of the plants were therefore grasses, whereas before burning they constituted only about one-twelfth. Except for further growth of these—the only plants on the plots—and the appearance of a few more sprouting species, no marked change occurred until after April when the winter rains had set in.

Enumerations in mid-winter and spring are summarised in Table II. If we compare with Table I we see a striking increase in the mean number of plants per quadrat. In January the mean number on unburnt quadrats was 222; in mid-winter the mean number on burnt and unburnt quadrats was 1201. This was due partly to the appearance in winter of many seedlings of various species—on the average 366 per four square-metre quadrat. These could not be identified. Apparently few of these survive the succeeding summer and large quantities of seed germinate every year, though few plants succeed in developing to maturity. Often it seemed as if a head of a composite or some such plant had fallen in one place so that a small, extremely dense colony of seedlings, one or two inches in diameter, was formed. From such a colony probably only one or two plants were likely to survive. The increase in the total number of plants observed was also partly due to the development of many geophytes which were not in evidence in the summer.

The burning of the sets of quadrats A to D on the 15th of January, February, March, and April respectively did not affect the total numbers of plants on the quadrats observed in mid-winter. Sprouting species survived the fire, and the numbers of seeds which germinated under the old unburnt vegetation were equal to those germinating on the open burnt quadrats. There were also no significant differences in the numbers of geophytic plants. *Oxalis* rosettes were somewhat fewer on the most recently burnt quadrats, but they were still developing, and the full numbers were probably not yet out on these quadrats at the time of observation. The most striking difference between burnt and unburnt quadrats was that the cover on the burnt quadrats was much less, and because they were more open the small seedlings and geophytes could be easily seen. A casual observer might have been led to suppose that there were more seedlings and more geophytes on the burnt quadrats, but the actual enumerations dispelled this impression. The experiment provided no evidence at this stage that germination of seeds and development of geophytes were either promoted or retarded by fire.

The dominant plant before burning, *Anthospermum aethiopicum* L., was present in winter and spring as small seedlings only, which could not be identified with certainty.

The most abundant species in mid-winter, apart from *Oxalis purpurea* L., if all rosettes of this species are taken as individuals, was *Ficinia capillaris*

Nees ex Levyns. There were many small seedlings of the *Ficinia*, as well as old plants that were sprouting.

Grass plants appeared to have doubled their number, but this might have been due to the fact that grass tufts counted as one plant in January often appeared to consist of several plants when sprouting after burning.

The most conspicuous of the monocotyledonous geophytes were *Micranthus plantagineus* Eckl., *Babiana plicata* Ker., and *Hexaglottis longifolia* Vent. (see Pl. XXIV, figs. 16 and 17).

Many striking species occurring in the sclerophyll scrub, for example *Gladiolus blandus* Soland., are so widely scattered that they might occur only once or twice on an area as large as that covered by the entire experiment. To determine the effect of burning on the development of such plants experimentally would naturally be a difficult special problem beyond the scope of an experiment such as the one which is being described here.

Sprouting and Height Growth of Selected Species.

The secondary succession after fire in the sclerophyll scrub vegetation of the Cape is always characterised by the rapid development and flowering of grasses, dicotyledonous therophytes, *Oxalis* species and other geophytes. In the second stage of the succession the shrubby species sprouting from root-stocks play the dominant rôle. In time more and more shrubs re-developing from seed become mixed with these. In places tree-like species, well insulated against the heat of fire by thick corky bark such as *Protea grandiflora* L. and *Gymnosporia laurina* Bolus and Wolley-Dod (Wicht, 1945), survive repeated burning for many years, possibly as long as one hundred years or more in some instances. On the experimental site such species were absent, and the sub-climax (Weaver and Clements, 1938), which was being approached on this site before the application of burning, was dominated in all seasons by shrubs sprouting from root-stocks or re-developing from seeds. Inspection of surrounding vegetation led to the conclusion that the associes on the experiment site might in time have been replaced by one in which taller shrubs such as *Protea mellifera* L. (from seed), *P. pulchella* Andr. (from seed), *Royena glabra* L. (sprouting), and *Rhus tomentosa* L. (sprouting) played the dominant rôle. Eventually even taller species like *Gymnosporia laurina* Bolus and Wolley-Dod, would probably have invaded the area. Before application of the experimental burning-treatments, the smaller sprouting species probably still controlled the site. Those that were definitely established as sprouting species at the mid-winter enumerations after burning of the A to D quadrats were:

1. *Adenandra serpyllacea* Bartl.
2. *Aspalathus divaricatus* Thunb.

3. *Borbonia parviflora* Lam.
4. *Centella bupleurifolia* (Rich.) Adamson. (Woody stem buried in ground.)
5. *Clutia polygonoides* L.
6. *Diosma vulgaris* Schl.
7. *Gnidia Burmanni* E.Z.
8. *Hibiscus aethiopicus* L. (suffruticose).
9. *Leucadendron adscendens* R.Br.
10. *Montinia acris* L.f.
11. *Muraltia heisteria* DC.
12. *Phylica spicata* L.f.
13. *Podalyria myrtilliflora* Willd.
14. *Protea acaulis* Thunb.
15. *Rhus rosmarinifolia* Vahl.
16. *Rhus tomentosa* L.
17. *Salvia africana* L.
18. *Senecio pinifolius* Lam.
19. *Stoebe capitata* Berg.
20. *Stoebe plumosa* Thunb.

These species are all able to flower in the first or second season, after burning, before the veld has again become inflammable. It is possible that the development of species with this habit is favoured by burning. Some of the larger, more prominent shrubs on the area before burning which were observed to redevelop from seeds were:

Anthospermum aethiopicum L.
Borbonia cordata L.
Elytropappus gnaphaloides (L.) Levyns.
Helichrysum spp.
Metalasia spp.
Passerina vulgaris Thoday.
Protea pulchella Andr.

In the associes occupying the experimental site before burning the dominant heights of the species *Leucadendron adscendens* R.Br., *Montinia acris* L.f., and *Stoebe plumosa* Thunb. were measured. These were the most prominent of the sprouting species, and their heights gave an indication of the general height of the vegetation apart from the emergent individuals of *Anthospermum aethiopicum* L. The heights of these species were remeasured in mid-winter. There was naturally a highly significant difference between the burnt and unburnt quadrats (see Table II), and it is also clear that the growth was less advanced the more recently the quadrats had been burnt.

Flowering of Oxalis and other Species.

At the mid-winter enumeration *Oxalis purpurea* L. and *Oxalis versicolor* L. were flowering freely. There were, however, no significant differences in number of plants or number of flowers between burnt and unburnt quadrats. In September when *Oxalis* plants were again examined it was noted that *Oxalis versicolor* L. was no longer in flower, and that a number of other species had come into flower in addition to *Oxalis purpurea* L. *Oxalis versicolor* L. is a caulescent species which apparently flowers equally well in the open and in between shrubs. The species flowering in September, however, definitely favoured the open burnt quadrats, and a highly significant greater number of flowers were found on these (see Table II).

At the mid-winter enumerations there were very few flowers other than those of the *Oxalis* species on the burnt quadrats. On the plots burnt in April there were none, on the quadrats burnt in March one *Asparagus Thunbergianus* Schult f. was in flower, while on the quadrats burnt in February four *Clutia polygonoides* L., and on the quadrats burnt in January two of the *Clutia* and one *Rhus rosmarinifolia* Vahl. were flowering. The *Clutia* was also flowering on unburnt quadrats. On these unburnt quadrats fresh flowers of *Diosma vulgaris* Schl., *Muraltia heisteria* DC. and *Senecio pinifolius* Lam. were also observed. The flowers of *Leucadendron adscendens* R.Br. were going over, and *Stoebe* spp. were carrying dead flowers for the most part.

It was particularly desired to ascertain whether the burning in the previous summer and autumn would affect the flowering of geophytes in the spring. The examination of species of other genera than *Oxalis* was, however, not very satisfactory. Most species were so thinly distributed that they were not represented on many of the quadrats, so that it was impossible to determine whether the distributions were fortuitous or not. It is also unfortunate that, due to circumstances beyond control, the area could not be more frequently and thoroughly inspected during the spring. The following observations were, however, recorded.

Inspections in mid-September revealed that the liliaceous geophytic species *Androcymbium leucanthum* Willd. was still in flower, and that this species had flowered only on burnt quadrats. The species has a corm and an underground stem 2 to 3 inches long. The leaves and head of flowers are formed on the ground surface.

In September the geophyte, *Babiana plicata* Ker., was flowering freely on the area, but an enumeration of the number of flowering plants on the quadrats did not provide evidence that the flowering had been affected by the burning (see Table II).

In September many shrubby species were flowering only on quadrats

that had not been burnt before the winter. These included *Protea pulchella* Andr., *Diosma vulgaris* Schl., *Muraltia heisteria* DC., *Oedera prolifera* L.f., and *Metalasia* spp. It could in fact be shown that the number of plants other than *Oxalis* species in flower on unburnt quadrats were highly significantly higher than those in flower on burnt quadrats (see Table II).

Grasses on burnt quadrats had not yet reached the flowering stage by the end of winter and in the first half of spring (see Table II). On unburnt quadrats many grass plants were flowering.

On the burnt quadrats the sprouts of *Leucadendron adscendens* R.Br. and *Montinia acris* L.f. were in flower only on the quadrats burnt in January, and sprouts of *Podalyria myrtilliflora* Willd. were in bud on quadrats burnt in January and February. It would seem, therefore, that burning in the late summer or autumn might cause these sprouting species to miss the flowering season in spring, or at least delay flowering considerably.

The general conclusions appear to be justified that burning in summer and autumn will generally promote the flowering towards the end of winter and in spring of *Oxalis* species, other geophytes, and probably also of some therophytes, but that such burning will prevent the flowering, for one season at least, of many perennial shrubby species, especially those that redevelop from seed. It also appeared probable that late burning in autumn was more unfavourable for flowering in spring than burning in mid-summer.

SUMMARY.

After an introductory discussion of the application of statistical methods in plant ecological research, a statistically planned experiment to test burning of sclerophyll scrub vegetation in spring, summer, and autumn months at the Jonkershoek Forest Research Station, Stellenbosch, Cape Province, is described.

Preliminary analyses show the variability of the vegetation on the experimental site and give an advance indication of the sensitiveness of the experiment.

The results of burning carried out in the months January to April, as observed in the succeeding winter and spring, are presented and discussed. It is proposed to publish further accounts of experimental results from time to time.

The description of the experiment indicates some of the ways in which statistics can be used in order to advance the study of South African vegetation from the descriptive to the analytical stage.

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Fig. 1.—Lay-out of Experiment to test Effects of Burning on Sclerophyll Vegetation.

Fig. 2.—Unburnt vegetation six and a half years old. Tall *Anthospermum aethiopicum* L. is about 60 inches high. Lower shrubs include *Leucadendron adscendens* R.Br.; *Stoebe plumosa* Thunb.; *Montinia acris* L.f.; *Royena glabra* L. and *Rhus tomentosa* L.

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FIG. 4.—Photo on plot A1 immediately after burning in January 1945. Layer of ash covers ground, and grass tufts, reduced to ash, have not yet disintegrated. Dead stems are *Leucadendron adscendens* R.Br.

FIG. 5.—Photo on plot A1 one month after burning. Ash blown away and soil bare. *Montinia acris* L. sprouting on left.

Fig. 6.—*Danthonia stricta* Schrad. sprouting 54 days after burning in January. Sprouts about six inches long.

Fig. 7.—*Leucadendron adscendens* R.Br. sprouting 54 days after burning in January. Sprouts about four inches long.

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FIG. 9.—Photo taken on plot A2, 163 days after burning, in same position as fig. 8. *Stoebe* has grown faster and is now larger than *Themeda*. Note leaves of *Oxalis purpurea* L. in foreground.

FIG. 8.—Photo taken on plot A2, 72 days after burning. *Themeda triandra* Forsk. and *Stoebe plumosa* Thunb. sprouting. Green leaves of *Themeda* about 3 inches long.

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FIG. 10.—*Stoebe plumosa* Thunb. sprouting 54 days after burning in January. Sprouts about one inch long.

FIG. 11.—*Oxalis purpurea* L. in flower, 169 days after burning in January.

FIG. 12.—General view of plot A1, 72 days after burning.

FIG. 13.—General view of plot A1, 163 days after burning. *Montinia acris* L.f.; *Leucadendron adscendens* R.Br.; *Salvia africana* L.; *Clutia polygonoides* L.; *Asparagus Thunbergianus* Schult. f.; *Themeda triandra* Forsk. and *Oxalis* species could be identified.

FIG. 14.—Photo taken on plot A1, 163 days after burning in January. Plants seen in photo are *Themeda triandra* Forsk.; *Salvia africana* L.; *Montinia acris* L.f.; *Clutia polygonoides* L. (in flower); *Babiana plicata* Ker.; *Oxalis purpurea* L.; *Hexaglottis longifolia* Vent.; *Leucadendron adscendens* R.Br.; and *Diosma vulgaris* Schl. Rule equals 1 metre.

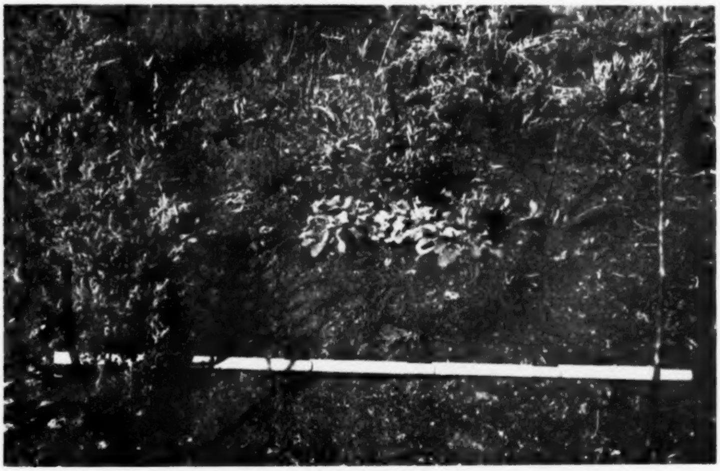

FIG. 15.—Photo taken on plot B1, 132 days after burning in February. Plants seen in photo are *Salvia africana* L.; *Asparagus Thunbergianus* Schult. f.; *Podalyria myrtilliflora* Willd.; *Oxalis purpurea* L.; *Ficinia capillaris* Nees ex Levyns, and *Centella bupleurifolia* (Rich.) Adamson. Rule equals 1 metre.

C. L. Wicht. *Neill & Co., Ltd.*

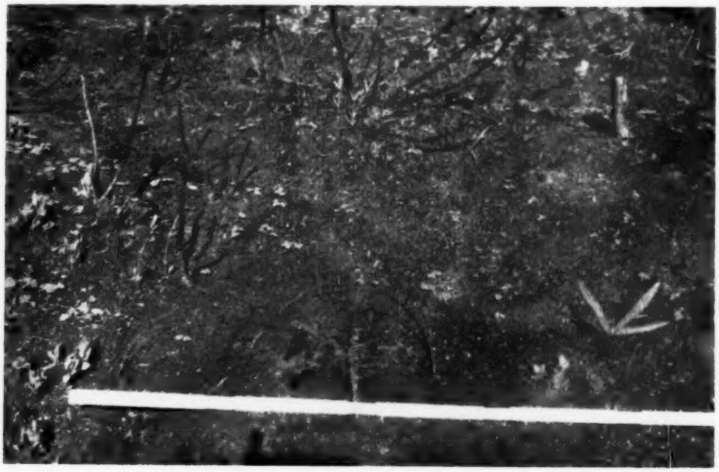

FIG. 16.—Photo taken on plot C1, 104 days after burning in March. Plants seen in photo are *Babiana plicata* Ker.; *Oxalis purpurea* L.; *Salvia africana* L.; *Montinia acris* L.f.; *Hexaglottis longifolia* Vent.; and *Leucadendron adscendens* R.Br. Rule equals 1 metre.

FIG. 17.—Photo taken on plot D2, 74 days after burning in April. Plants seen in photo are *Micranthus plantagineus* Eckl.; *Ficinia capillaris* Nees ex Levyns; *Oxalis purpurea* L.; and *Babiana plicata* Ker. Rule equals 1 metre.

SIR CARRUTHERS BEATTIE, D.Sc., F.R.S.E., AND HIS SCIENTIFIC WORK.

By Lawrence Crawford.

(Read October 16, 1946.)

John Carruthers Beattie was born on 21st November 1866, in Cumberland, but soon afterwards his parents with him went to live in Dumfriesshire. He died on 10th September 1946, at Kenilworth, Cape Town.

He entered as a student at Moray House, Edinburgh, the training college for teachers, for its two-year course, in 1884; he studied at the University of Edinburgh and took the B.Sc. degree. He was Newton Bursar in Natural Philosophy, 1891–2, Vans Dunlop Scholar 1892–4 and 1815, Exhibition Research Scholar, 1894–6. From 1892 to 1896 he studied at Munich, Vienna, Berlin and Glasgow. In 1896 he took the D.Sc. degree at the University of Edinburgh.

In 1897 he was appointed Professor of Applied Mathematics and Physics at the South African College, Cape Town, and when the Chair was divided in 1904 he became Professor of Physics. He held this post until 1917, when he was appointed Principal of the College; it was incorporated with the University of Cape Town in 1918, and he was Vice-Chancellor and Principal of the University until the end of 1937, when he retired.

Beattie's early scientific papers, Nos. 1, 2, 3, 4, 5, 6, 8, 10 on the appended list, were on the influence of X-rays, ultra-violet light, and the rays from uranium on the electrical conductivity of gases, and on the effect of temperature on the leakage of electricity across an air condenser whose plates were treated with various inorganic substances. These investigations were amongst the earliest made on the important subject of the emission of electricity by hot bodies, which is now of such great technical importance, and they became the foundation of important subsequent work. In "The Emission of Electricity from Hot Bodies," one of a series of monographs on Physics, dated 1916, there is the remark, "The effect of the pressure of various inorganic substances on the leakage of electricity across a parallel plate air condenser at temperature in the neighbourhood of 300° C. was examined by Beattie," and the statement that these phenomena were subsequently investigated by various men from 1904 to 1911. Paper No. 5 was the first paper signed by him with the address South African College;

it was read before the South African Philosophical Society, but it was published in the Philosophical Magazine.

In 1898, in conjunction with Professor J. T. Morrison of the Victoria College, Stellenbosch, Beattie began the great work of a Magnetic Survey of South Africa, and from then for some seventeen years his vacations were given up to observations of magnetic dip or inclination, declination and horizontal intensity, at stations all over South Africa, and to the calculation, with help from others, from the observations of the values of those elements. The first paper on magnetic work, No. 9 in the list, "The Magnetic Elements at the Cape of Good Hope from 1605 to 1900," was given to the South African Philosophical Society in 1901, and published in the Transactions of the Society, vol. xiv, Pt. 1, 1903.

In 1905 Beattie wrote the article "Earth Magnetism in South Africa" for the book Science in South Africa, issued to the members of the British Association who came out to South Africa for the 1905 meeting. The results of the magnetic observations made by Beattie and Morrison from 1898 to 1906 were printed in a volume of 350 pages by the Cambridge University Press, and published for the Royal Society of London in 1909. In the preface it is stated that about 300 stations were occupied in the year 1903, when Beattie and Morrison had leave for the year, and in all the results were given for 405 stations. A general account of the Survey is given, including distribution of stations, instruments, methods of observation and errors of observation. Papers Nos. 18 and 20 are based on this Royal Society report.

In 1909 Beattie and Morrison had again leave for the year and spent it in magnetic observations. At the end of November 1908 Beattie started on his journey from Ceres to Windhoek, largely done by ox-wagon. His route was Ceres, O'Okiep, Pella, Rahman's Drift, Henkriesfontein, O'Okiep again, Rahman's Drift, Holoog, Keetmanshoop, Lüderitz, Keetmanshoop, Windhoek, completing this by the end of March 1909. In May the two observers set out from Broken Hill, the only means of transport being porters. The march began at sunrise and usually continued from 15 to 18 miles till nearly noon; camp was then pitched and observations made in the afternoon. The route was through North-West Rhodesia, the Belgian Congo and North-East Rhodesia to Abercorn. At Abercorn the two separated, and Beattie began the arduous task of working through to Gondokoro on the Nile. The route Abercorn, Bismarckburg, Tabora had to be done entirely by land, as Lake Tanganyika was a closed area owing to sleeping sickness; the rest of the journey was Tabora, Bukoba, overland to Entebbe, Butiaba, by boat to Koba (the journey via Butiaba and Koba was necessary owing to sleeping sickness), Gondokoro. In September, between Tabora and Bukoba, the small rainy season set in, fever became

rife among the carriers, Beattie himself began to suffer from fever and was unable to throw it off during the rest of the journey; the food supplies were bad, the tent and bedding were constantly wet and the mosquitoes became very troublesome, delays ensued through fever, dysentery and bad weather. Later the journey from Koba to Gondokoro was very trying; rain often fell at night and the rivers running into the Nile were nearly all in flood; fever was prevalent, and the temperature during the day and night was much too high for comfort. Altogether, this part of the journey was very exhausting, and it was with great relief that Beattie was able to dismiss his caravan at Gondokoro and take boat for Khartoum. It might be added that Morrison went from Abercorn to Lake Nyassa, then through Nyassaland to Port Herald, by boat along the Shire and Zambesi rivers to Chinde, then from Dar-es-Salaam to Morogoro by railway, thence to Mombasa and along the railway from there to Port Florence (Kisumu).

The results obtained by Beattie and Morrison for these 1908–1909 journeys were published by the Carnegie Institution of Washington, in Publication No. 175, 1912, "Land Magnetic Observations, 1905–1910," by L. A. Bauer, Director of the Department of Terrestrial Magnetism, along with accounts of the expedition by Beattie and by Morrison, Paper No. 21. The distribution of stations occupied by the two observers was as follows: jointly, six in the Belgian Congo, one in the Cape Province, one in Egypt, one in England and thirty-nine in Rhodesia—in all forty-eight; by Beattie, thirty-six in the Cape Colony, forty-five in German South-West Africa, sixty in German East Africa, three in Rhodesia and thirty-three in the Uganda Protectorate—in all one hundred and seventy-seven; by Morrison, thirty-five in British Central Africa, twenty-eight in British East Africa, four in the Cape Colony, ten in German East Africa, twenty-four in German South-West Africa, six in Portuguese East Africa, fifteen in Rhodesia and one in Zanzibar—in all one hundred and twenty-three.

In 1910–13 sixty-four new stations were occupied, mainly in Western Transvaal, Bechuanaland and Bushmanland, where hardly any observations had been taken. The results are given in Paper No. 22.

In Paper No. 24, "The Secular Variations of the Magnetic Elements," Beattie says that the study of the secular variations of the magnetic elements in South Africa is of more than usual interest because of the abnormal values of the changes, and states that the naval charts showed such changes off the East African Coast.

In 1913–15 twenty-five new stations were occupied; the results are given in Paper No. 25.

Beattie served frequently on the Council of the South African Philosophical Society; he was President 1905–6, and he gave an address in 1906 on "Some Physical Problems in South Africa." He was one of the first

Fellows of the Society, he served on the Council in 1910, 1911, 1914, 1916, 1918, 1919, and was Secretary 1912, 1913, 1914 (to July).

In 1910 he was President of Section A of the S.A.A.A.S., and in the same year he was awarded by the Association the South Africa Medal and Grant; the fund for this was the gift of members of the British Association after its visit to South Africa in 1905. He was President of the Association in 1928.

Beattie had always taken a big part in the "University" question, and the plan of the South African College to develop, under its own charter, as a teaching university; the battle for this lasted from 1904 to 1916, and is described graphically by Walker in his Centenary History of the South African College and the University of Cape Town. From 1905 Beattie was the assessor elected by the Senate on the College Council, in 1911 he took over the headship of College House, and when in 1916 he became a member of the Statutes Commission to draw up statutes for the Universities, for which the Acts had gone through Parliament, followed in 1917 by his election as Principal of the College and in 1918 by his election as Vice-Chancellor and Principal of the University of Cape Town, the scientist became wholly the Administrator, and, while he encouraged research at the University, his own research work came to an end.

As Principal and Vice-Chancellor of the University of Cape Town he did outstanding work in administering the new University; on him fell largely the burden of planning and carrying out the building programme at Groote Schuur, and transferring the University from Cape Town to its new seat in 1928–29. The great development of the University is due largely to his influence, and in the history of the University he will always be a great figure through his wonderful work in its early days. His work for higher education was fittingly recognised by the knighthood conferred on him in 1920.

Beattie participated actively in the work of other bodies: the South African Public Library, the South African National Gallery, the Scientific and Industrial Research Committee, the Industries and Science Board, the Survey Commission (Chairman in 1921), the Mining Industry Board, the Technical Colleges Committee of Enquiry, and the South African Broadcasting Board. He is survived by his wife, whom he married in 1898, and two married daughters. His only son, who did service in the Great War in 1918 as a Lieutenant in the R.A.F., joined for service in the R.A.F. in the Second World War, and was killed in 1942.

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22. BEATTIE on "Further Magnetic Observations in South Africa," Transactions of R.S.S.Afr., vol. iv, part 1, 1914, p. 9.
23. BEATTIE on "True Isogonics, Isoclinals and Lines of Horizontal Intensity for the North-Western Parts of the Union of South Africa and for part of Great Namaqualand for the Epoch July 1, 1908," Transactions of R.S.A.Afr., vol. iv, part 1, 1914, p. 57. (Results are given for 255 stations and 3 maps are drawn, showing (i) isogonics, (ii) isoclinals, (iii) lines of equal horizontal intensity.)
24. BEATTIE on "The Secular Variation of Magnetic Elements in South Africa during the Period 1900–13," Transactions of R.S.S.Afr., vol. iv, part 3, 1915, p. 181. (Read 1914. Based on results of previous work and on observations in Katanga district of Congo, also on observations by B. F. E. Keeling in North Africa. With 3 maps showing secular variations of magnetic declination, dip and horizontal intensity, and two appendices giving (i) results of observations at repeat stations, (ii) results of further observations.)
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TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXXI.

MINUTES OF PROCEEDINGS.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 17, 1943, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Annual Report of the Hon. General Secretary for 1942 was read and passed.

The Annual Report of the Hon. Treasurer for 1942 was read and passed.

As due and proper notice of the Election of Officers and Council for 1943 had not been given, the President moved that voting take place, but that the completion of the election be postponed until 21st April. This was agreed to.

Ordinary Meeting.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of 18th November were passed.

The Abbé Henri Edouard Prosper Breuil was elected unanimously to Honorary Fellowship of the Society.

Henri Breuil. At an early age the Abbé Breuil took up the study of prehistoric archaeology. During over forty years of study he has inspired the work of researchers in France, England, Germany, China, Mesopotamia, Palestine, North Africa, Abyssinia, East Africa, the

Belgian Congo, and Southern Africa. He himself has visited most of these areas, and has made important first-hand discoveries throughout the Old World. He has published several hundreds of scientific papers, and in the course of his work has discovered many new approaches to his subject, dating certain deposits geologically, others in relation to cave paintings, and so on.

His standard of work has always been regarded as a model of excellence, and we may take it as an honour to this Society that he is now an Honorary Fellow. He is universally regarded as the greatest prehistorian of the century, and in a science which started in about 1870, he may legitimately be looked upon as the greatest figure so far produced.

H. H. DODDS was elected to Membership of the Society.

The following were nominated for election to Membership of the Society: W. A. BISHOP, proposed by E. NEWBERY, seconded by W. J. TALBOT; G. BRAUSCH, proposed by J. F. SCHOFIELD, seconded by A. J. H. GOODWIN; L. E. KENT, proposed by A. L. DU TOIT, seconded by A. W. ROGERS; N. SAPEIKA, proposed by H. ZWARENSTEIN, seconded by H. A. SHAPIRO.

The President announced with regret the deaths of the following Life Members of the Society: P. R. MALLESON, and WILLIAM FLINT.

PERCY RODBARD MALLESON. Born at Gloucester, and attended Oxford University, later studying fruit-growing at the Toddington Orchard Company farm. He was appointed manager, and in 1892 was asked to take over the management of the Cape Orchard Company, and develop the fruit export trade. In its early stages this trade was very largely indebted to his pioneer work. He developed the company's interests in the Hex River Valley, importing suitable stock from Australia, America, and elsewhere. In 1908 he resigned his position and retired to his farm in Ida's Valley. Mr. Malleson was a Life Member of this Society.

WILLIAM FLINT. The Rev. Dr. Flint was born at Standbridge, Beds, in 1854, and was educated at Leighton Buzzard and Headingley College. He was appointed to the Methodist Church at Pietermaritzburg in 1891, and to the Rosebank Church in 1894. He was first Editor of the *Methodist Churchman*, and inaugurated the Methodist Bookroom, Cape Town. He was a foundation member, and an active member of Council, of the S.A.A.A.S., of which he was President in 1918. From 1901 to 1921 he was Librarian to the Cape of Good Hope Parliament, later the Union Parliament. He was appointed a member of the Council of the University of the Cape of Good Hope in 1903, and held office in that body and the University of South Africa until 1936. He was for a time Chairman of Council of the Huguenot Uni-

versity College. In 1927 he was appointed President of the South African Methodist Conference and Principal of the Theological College at Mowbray. He was among the founders of the Rondebosch Boys' High School and of the Rondebosch Cottage Hospital. He was a Life Member of this Society.

Communications:—

"The Relationship between the Field Characters, Microscopic Structure, and Physical Properties of Cape Road Stones." By FREDERICK WALKER and GEORGE STEWART.

"Curve Fitting by means of the Orthogonal Polynomials in Binomial Statistical Distributions." By H. T. GONIN.

"The Kinetics of Oxidation of Organic Compounds by Potassium Permanganate. Part V. Picric Acid." By L. M. HILL and F. C. TOMPKINS.

"A Consideration of the Dentition of the Crocodile, with special Reference to the Replacement of Teeth." By F. GORDON CAWSTON.

A comparison is made between the African crocodile *Crocodilus niloticus* Laurenti and *Gavialis gangetica*, a fish-eating species from India, to show that many of the teeth remain in use throughout life and, as there is an open apex to each tooth, continue to grow. When other teeth are lost each vacant space is shortly filled by a successional tooth of which there are usually two lying loose in the jaw of the African species, just below each functional tooth.

These unerupted teeth are quite independent of the functional ones and there is no attempt at hastening their shedding, as the permanent set of mammalian teeth displaces the deciduous.

Eruption takes place at regular intervals in the Indian jaw and in most portions of it the interspaces are approximately equal.

"Notes on Dr. Cabu's Collection of Stone Implements from the Belgian Congo." By C. VAN RIET LOWE.

"Les Industries Paléolithiques de la Terrasse de 15 Metres et d'une Chenal secondaire comblé, Plaine de Piemont de Léopoldville, d'après les Fouilles et Photographies du Dr. Cabu." Par l'Abbé HENRI BREUIL. (Etude suivie d'une Note de commentaire. Par le Dr. F. CABU.)

"Le Paléolithique du Congo Belge, d'après les Recherches du Dr. Cabu." Par l'Abbé HENRI BREUIL.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 19, 1943, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The President announced that, as no quorum was present on the evening of Wednesday, April 21, 1943, no meeting was held. The two communications listed had been read to those present. The Minutes of the Ordinary Meeting of March 17, 1943, were passed, after one emendation. (PETER ROBERT MALLESON to read PERCY RODBARD MALLESON.)

The President announced that, as no objection had been raised consequent upon the oversight in the Election of Council for 1943, he declared the following to be duly elected:—

President, A. BROWN; Hon. Treasurer, R. W. JAMES; Hon. General Secretary, A. J. H. GOODWIN; Hon. Editor of Transactions, A. L. DU TOIT; Hon. Librarian, E. NEWBERY; Council: H. G. FOURCADE, S. H. HAUGHTON, J. JACKSON, R. F. LAWRENCE, S. H. SKAIFE, J. SMEATH THOMAS, C. VON BONDE, C. L. WICHT.

The following were duly elected to Membership of the Society: W. A. BISHOP, G. BRAUSCH, L. E. KENT, N. SAPEIKA.

The following Nominations to Membership were announced: B. T. SQUIRES, proposed by I. SCHAPERA, seconded by A. J. H. GOODWIN; A. M. VAN WIJK, proposed by A. OGG, seconded by A. BROWN; B. GOTSMAN, proposed by A. OGG, seconded by A. BROWN.

Communications:—

*"Universal Buffer Solutions." By E. NEWBERY.

"The Development of the Arterial System of Xenopus." By N. A. MILLARD. Communicated by R. S. ADAMSON.

"The Cytological Basis of Variation in Varieties of *Nicotiana tabacum*." By A. A. MOFFETT. Communicated by G. ARNOLD.

Lecture.—* "Historical Sketch of Tunisia." By A. J. H. GOODWIN.

Discussion.—"Preservation of Mountain Vegetation of the South-West Districts of the Cape Province." By J. S. HENKEL. The Discussion was opened by A. L. DU TOIT.

The subject was considered to be of sufficient interest to merit further discussion. It was agreed that J. S. HENKEL's paper be submitted to the next Meeting of Council with a view to further appropriate action.

* Papers marked with an asterisk were unofficially read on April 21, 1943, and were included once again in this evening's business. Fellows and Members are once again asked to make an effort to attend meetings, in spite of the difficulties entailed by black-out regulations, as failure to hold a meeting impedes the business of the Society, and retards publication.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 16, 1943, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting for May 19, 1943, were passed.

The following were elected to Membership of the Society: B. T. Squires, R. Gotsman, and A. M. van Wijk.

The President announced the decision of Council to hold future meetings of the Society in the afternoons, at the buildings of the Royal Observatory, Observatory, Cape Town. After discussion, Dr. L. Crawford proposed that the matter be referred back to Council for reconsideration.

Communication:—

"Skeletal Maturation, Somatometric Indices, and Blood Haemoglobin Level in the Detection of Human Malnutrition." By J. M. Latsky, A. R. Richardson, and J. F. Brock.

Certain data derived by the Cape Nutrition Survey relative to human malnutrition have been submitted to statistical analysis to discover whether they could be correlated with assessment of the children into normal and malnourished groups by clinical appraisal according to the Dunfermline scale. The data consisted of three indices:—

1. Flory's skeletal maturation index. X-rays of the right carpus are examined and the skeletal age of the child determined by reference to standards established by Flory on American children. The assessment is not regarded as highly accurate, but it was made without bias.

2. Wetzel's developmental age is an index derived from height and weight in relation to age. The developmental age of the child is determined by reference to an auxodrome expressing the developmental level reached by 67 per cent. of Wetzel's American children.

In both Flory's and Wetzel's indices a given child is assessed as advanced or retarded by a given number of years with reference to the American standards.

3. The blood haemoglobin determined by a Sicca haemometer calibrated at 100 per cent. for 13·8 grams of haemoglobin per 100 c.c. of blood. The accuracy is ± 1 per cent.

The statistical analysis was concerned mainly with a comparison between 210 normal Cape coloured children and 210 malnourished Cape coloured children, the two groups having identical mean ages and age distributions. The following conclusions were drawn:—

Although, owing to the very large overlap between the distributions of Hb level, skeletal and developmental advancements, single measure-

ments of these indices have only a limited value in the detection of malnutrition in the individual, yet in large groups there are statistically significant differences in the statistics. These differences may be used in the detection of malnourishment in large groups if due precautions are taken in interpreting the results. The parameters have not been determined yet.

The paper was followed by a Discussion on the "Applicability of Statistical Methods to Biological Data."

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 11, 1943, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting for June 16, 1943, were passed.

The following were nominated for Election to Fellowship of the Society: JOHN GEORGE ROSE, Col., D.S.O., V.D., F.I.C.; HILLEL ABBE SHAPIRO, Ph.D., M.B., Ch.B.

The President announced that Meetings of the Society will in future be held at the time and place originally arranged on the Session Card. Meetings will therefore be held on the second Wednesday of each month, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Astronomer Royal, Dr. Jackson, extended an invitation to Members and Fellows of the Royal Society of South Africa to attend a meeting of the Astronomical Society, to be held on Wednesday, 18th August, as a Centenary Meeting in memory of Sir David Gill, at the Royal Observatory.

After debate it was agreed that papers may be returned to the author if they do not include a précis suitable for reading at the Meeting of the Society, and for inclusion in the Minutes of Proceedings. (Statutes, Chap. X, 3.)

Communications:—

"The Labrid Fishes of Portuguese East Africa." By MARGARET M. SMITH.

"A Revision of the Genus Agrostis, Linn., in South Africa, with special Reference to Leaf Anatomy." By A. P. GOOSSENS and M. C. PAPENDORF.

"Notes on some Aspects of Madagascar Geology and Archaeology." By J. D. CLARK.

The plateaux around the harbour of Diego Suarez are built of Mesozoic and Tertiary marine strata, since elevated, tilted, and faulted, followed by the Pleistocene lavas of the Ambre Mountains. Wind-blown sand covering the 50-metre raised beach at Ankorika Camp yielded fragments mostly of pottery made of fairly fine clay, commonly burnished, and showing incised decoration. Such points to a fairly developed culture with the probable use of iron implements. (EDITOR.)

"Short Notes on Stone Age Sites at Yavello, Southern Abyssinia." By J. D. CLARK.

"A Kenya Fauresmith Factory and Home Site at Gondar, Northern Abyssinia." By J. D. CLARK.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 8, 1943, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Meeting of August 11, 1943, were passed.

The President referred briefly to the Centenary of the birth of Sir David Gill which occurs in 1943. Sir David became a member and President of the Philosophical Society on July 31, 1879, and for many years exercised a predominant influence on scientific work in South Africa. His reputation as an astronomer of world standing is well established, and South Africa, and in particular the Royal Society of South Africa, are glad to be associated with his work and its developments.

The following were duly nominated for Membership of the Society: J. T. R. SIM, proposed by C. L. WICHT, seconded by A. J. H. GOODWIN; G. G. SMITH, proposed by J. L. B. SMITH, seconded by E. D. MOUNTAIN.

Communications:—

"New and hitherto imperfectly known Species of African *Restionaceae*." By N. S. PILLANS. Communicated by L. BOLUS.

"A Consideration of the Successful Theory as applied to the Dentition of *Pagrus nasutus* (The Mussel-crusher) and some Reptiles." By F. GORDON CAWSTON.

Discussion.—"The Present State of Research on Fish Oils." By H. M. SCHWARTZ, N. J. VAN RENSBURG, and E. ROUX.

A. J. H. GOODWIN,
Hon. General Secretary.

Annual Meeting.

The Annual Meeting of the Society was held on Wednesday, October 13, 1943, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The following were elected to Fellowship of the Society:—

John George Rose.—For distinguished work as Government Analyst and as Chief Chemist to the South African Railways and Harbours, in relation to the establishment of Railway Laboratories, water treatment, metal recovery, re-organisation of oiling system, etc.

Hillel Abbe Shapiro.—For outstanding work as Assistant Government Pathologist at Cape Town and publications on experimental physiology, malnutrition, etc.

Ordinary Meeting.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of September 8, 1943, were passed.

Karel Lodewyk Jan Blommaert was nominated to Membership.

J. T. R. Sim and G. G. Smith were elected to Membership of the Society.

Communications:—

1. "Earth Movements, Pluviation and Ice Ages."

A discussion of a general theory applicable to most climatic phenomena during man's history, in the light of periodical accumulation of radioactivity and sun-heat.

2. "Climates and Pre-Palaeolithic Artifacts of the Witwatersrand."

3. "Stone Implements of the Eastern Limpopo Basin."

By J. C. Smuts (Jun.). Communicated by C. van Riet Lowe.

Lecture.—"Ten Years of the *Xenopus* Pregnancy Test." By H. Zwarenstein.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 10, 1943, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 13, 1943, were passed.

J. G. Rose was received as a Fellow of the Society.

K. L. J. Blommaert was elected to Membership of the Society.

Margaret Metcalfe, proposed by J. F. Schofield, and seconded by E. C. Chubb, was nominated for Membership of the Society.

Nominations for election to Council for 1944 are as follows:—

President, A. Brown; Treasurer, R. W. James; Secretary, A. J. H. Goodwin; Editor of Transactions, A. L. du Toit; Librarian, E. Newbery. Members of Council: H. G. Fourcade, * J. S. Henkel, J. Jackson, * L. F. Maingard, * E. P. Phillips, * J. G. Rose, J. Smeath-Thomas, S. H. Skaife, C. L. Wicht.

(* New Members of Council.)

Retiring Members: R. F. Lawrence, S. H. Haughton, C. von Bonde. Council is thus brought up to its original strength in accordance with the Statutes of the Society.

Communications:—

"A Consideration of the Solid Teeth of some Venomous and Non-venomous Snakes found in South Africa." By F. Gordon Cawston.

Examination of the solid teeth of various venomous and non-venomous snakes found in South Africa shows that the small, straight hinder teeth which lie in the wall of the *vagina dentis* and have been regarded as "successional" are largely confined to the front portion of the mouth, those farther back usually consisting of one incomplete row invariably less than the number of socketed teeth, and often lying backwardly directed.

Alternate anchylosis of the socketed teeth is prevalent in various snakes, especially in the mandible and outer upper rows, and may sometimes be seen from end to end of a row. The loosely attached teeth are always less developed than the anchylosed but, unlike the hinder teeth, have recurved bases for attachment to the jaw. True anchylosis should be a permanent feature and no support is forthcoming for the view that a tooth can ever be shed once it has become anchylosed.

In every snake the size of the majority of its teeth corresponds with the size and age of the individual, the number of teeth being added to from behind each row as age advances. This number is specially large in some palatine rows where there would seem to be less use for the alternate anchylosis of the teeth, a phenomenon reminiscent of the dentition of the Barracuda Pike among fishes where newly erupting teeth are seen between the sockets of those in constant use.

Demonstration.—"Implement-bearing Diamondiferous Gravels of North-Eastern Angola." By J. Janmart.

A series of photographs, showing the disposition and relationship of

various gravels and quaternary deposits containing human artefacts from the earliest times, was projected. The question of the change of flow of streams, originally running north-west, to the existing northward-flowing pattern of the southern tributaries of the Kasai, was discussed.

A. J. H. Goodwin,
Hon. General Secretary.

CENTENARY OF SIR DAVID GILL.

The year 1943 is the centenary of the birth of Sir David Gill, and his connection with South Africa and with the Philosophical Society of South Africa (now the Royal Society of South Africa) makes it appropriate to recall his work and reputation.

He came to South Africa as Her Majesty's Astronomer at the Cape of Good Hope in 1879, and on 31st July of that year became a member and President of the Philosophical Society. He held the office of President for the usual period, and thereafter as a member of the Council exercised great influence on its work and on every department of scientific research in South Africa. The details of his achievements and of his character as a man and as a scientist are available in his Life by Forbes (1), in his own History of the Observatory (2), and in the Obituary Notices by Dyson for the Royal Society of London (3), and for Nature (4), and by Roberts for the Royal Society of South Africa (5).

The great reputation which he had during his life has been confirmed and increased by the passage of the years, and he is now regarded as one of the outstanding astronomers of the world of all time. His period was one of distinguished workers in astronomy; Newcomb and Kapteyn and Backlund were his contemporaries; and in that galaxy he shone as a star of the first magnitude.

From his earliest contact with Astronomy as an amateur he was attracted by the importance and the practicability of extreme accuracy. This tradition he carried from observation with small instruments into the finished work possible with the greatest refinements; in every case applying severe and continuous tests to the instrument, and insisting on the utmost care and skill from the observer. His earlier photographic work showed the same meticulous care, and demonstrated the possibility of applying close and accurate measurement to such records. This had an important influence in starting the systematic photography of the Southern sky which is a historical landmark in Fundamental Astronomy. Special mention should be made of his work in connection with the Geodetic Survey

of South Africa and the determination of the length of a long arc of meridian. This called for special abilities in organising a prolonged piece of work and in dealing with Government bodies that had to authorise and finance the expenditure. His geodetic standards of accuracy and scientific method have been inherited by the Trigonometrical Survey of South Africa, whose work of to-day is the continuation of Gill's brilliant start.

There are still some living among us who can recall the personality and charm of the man. He took a distinguished part in the social and public life of the community and especially endeared himself to the younger men of his time who were bent on research He was readily accessible and sympathetic, and made a special point of drawing out from these young men their ideas and intentions in regard to their own work. We look back on a distinguished scientist whose sound astronomical work is built into the foundations of the present structure of Astronomy, and whose South African work is still being carried on in accordance with his own traditions and standards. His services to the world at large and to South Africa in particular rank him among the really great ones in the history of Science.

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1. *David Gill: Man and Astronomer.* George Forbes.
2. *History and Description of the Royal Observatory, Cape of Good Hope*, by Sir David Gill.
3. Royal Society of London. *Proceedings*, A, vol. xci, 1915, p. xxvi (Dyson).
4. *Nature*, vol. 92, p. 635, Feb. 5, 1914. (Dyson.)
5. Royal Society of South Africa. *Transactions*, vol. v, 1915–16, p. 195 (Roberts).

ALEXANDER BROWN.

TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXXI.

MINUTES OF PROCEEDINGS.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 15, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The report of the Hon. General Secretary for 1943 was read and passed.

The report of the Hon. Treasurer for 1943 was read and passed.

The following were duly elected as Officers and Council for 1944:—President, A. Brown; Treasurer, R. W. James; Secretary, A. J. H. Goodwin; Editor of Transactions, A. L. du Toit; Librarian, E. Newbery; Members of Council; H. G. Fourcade, J. Jackson, L. F. Maingard, E. P. Phillips, J. G. Rose, J. Smeath-Thomas, S. H. Skaife, C. L. Wicht.

Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of November 10, 1943, were passed.

Margaret Metcalfe was elected to Membership.

A. J. Boyazoglu, proposed by C. L. Wicht, seconded by D. Hey, and V. S. Forbes, proposed by J. L. B. Smith, seconded by A. J. H. Goodwin, were duly nominated for election to Membership.

Communications:—

"The Essential Oil of *Agathosma apiculata* Meyer," by J. L. B. SMITH and D. E. A. RIVETT.

"The Warm Springs at Loubad," by LESLIE E. KENT.

"A Method for Estimating the Number of Random Groups of Adjacent Diseased Plants in a Homogeneous Field," by J. E. VAN DER PLANK (communicated by E. P. PHILLIPS).

"A Universal Temperature Scale," by E. NEWBERY.

An Ordinary Meeting of the Society was held on Wednesday, April 19, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of March 15, 1944, were passed.

The following were elected to Membership of the Society:—A. J. BOYAZOGLU and V. S. FORBES.

Lecture:—

"Twenty Years of Archaeological Classification," by A. J. H. GOODWIN.

A brief historical account of work, mainly classificatory, undertaken by the speaker from March 1924 onward, resulting in the present accepted classification of South African stone implement industries.

A. J. H. GOODWIN.
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 17, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of April 19, 1944, were passed.

The following were nominated to Membership of the Society:—Commander H. S. GRACIE, nominated by E. NEWBERY and A. BROWN. H. S. JAGER, nominated by A. J. H. GOODWIN and E. NEWBERY.

Communications:—

"A Time Reaction," by J. L. B. SMITH.

In reacting to form hexamethylenetetramine, a mixture of aqueous formaldehyde and ammonia undergoes a wide change of pH. The course of

the reaction, which is proportional to the concentration and to the temperature, may be followed visually by the use of suitable indicators.

"The Petrology of the Mount Arthur Dolerite Complex, East Griqualand," by A. POLDERVAART, communicated by F. WALKER.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 21, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of May 17, 1944, were passed.

Commander GRACIE and H. S. JAGER were elected to Membership.

Discussion:—

"*The Invasion Area.*" Speakers, Commander H. S. GRACIE, A. J. H. GOODWIN, W. K. SPENCER and F. WALKER.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 16, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of June 21, 1944, were passed.

The following were nominated for election as Fellows of the Society:—
ROBERT ALLEN DYER, D.Sc. (for outstanding research in the field of botany), proposed by A. J. FAURE, A. L. HALL, E. P. PHILLIPS and A. PIJPER.

NORMAN SAPEIKA, Ph.D., M.B., Ch.B. (for research in pharmacology and toxicology), proposed by LOUIS P. BOSMAN, M. R. DRENNAN, B. J. RYRIE and I. SCHAPERA.

LAWRENCE HERBERT WELLS, M.Sc., M.B., B.Ch. (for research in physical anthropology, prehistoric archaeology, ceramics and primitive technology), proposed by R. A. DART, ALEXANDER GALLOWAY, C. VAN RIET LOWE and H. R. RAIKES.

Symposium:—

"Citrus By-products," by D. Coghill.

"Fruit Dehydration," by P. W. Wissing.

In South Africa, tunnel dehydrators have been erected at important fruit centres by the Deciduous Fruit Board.

Equipment for cutting should be made of metal inert to fruit acids. Pears are peeled by a special guarded knife to reduce loss of fruit in peeling. Apples are peeled and cored in one operation by a special hand machine. A mechanical peeler for pears is being developed in the laboratory.

Solutions of common salt and potassium metabisulphite are used for dipping the fruit during processing, to check the action of the enzymes responsible for browning. The cut fruits are exposed to the fumes of burning sulphur for inactivating enzymes; enzyme activity is tested by means of benzidine and hydrogen peroxide.

Pears are sulphured and dehydrated as soon as possible after cutting, the maximum delay allowed being 3 hours and 18 hours respectively. The fruit is dried on the parallel-flow system at a temperature of 160–165° F. with a 30° F. drop along the tunnel. Apples are dried on the two-stage principle, the temperature at the hot end of the primary and secondary tunnels being maintained at 180–190° F. and 160° F. respectively.

Fruit also tried out on a commercial scale in the Union are peaches, nectarines, apricots, plums, grapes, citrus and guavas.

The most important advantages of dehydration over sun-drying are improved culinary qualities and higher vitamin retention. Moreover, the moisture content of fruit can be reduced to a low level, thus reducing the rate of deterioration during storage and eliminating losses through insect infestation.

"Inspection of Dehydrated Vegetables," by D. J. Dreyer.

The object of inspection is to maintain a high standard of quality.

At the Factory: All operations of processing, dehydration and packing are carefully checked. Irregularities in any stage of the process can thus be rectified immediately and spoilage with resultant rejection of the product avoided or minimised.

In the Laboratory: The inspector extracts representative samples from not less than 2 per cent. of the packed cans. These samples are finally tested for:—

(a) *Moisture Content*: The standard method involves the use of a vacuum oven for 20 hours at 70° C., the absolute pressure being less than half an inch of mercury and the ventilation 10 litres per hour.

(b) *Peroxidase Activity*: The ground sample is moistened with a mixture of equal volumes of 1·5 per cent. hydrogen peroxide and a 1 per cent.

solution of guaiacol in distilled water. The development of a red-brown colour within one minute indicates significant amounts of active peroxidase.

(c) *Sulphur Dioxide*: Where sodium sulphite is used in the blanching process, the sulphite content of the dried vegetables is determined by means of the Monier-Williams method.

(d) *Culinary Quality*: This test is to ensure that the product, when cooked, looks and tastes good. The sample is cooked and judged in respect of colour, flavour and texture by a panel of three tasters.

(e) *Effectiveness of Gaspacking*: Measurements are made of the amount of oxygen present in the inert atmosphere in which the products are packed. An analysis is made of the oxygen content of one out of every 50 tins, by means of a modified Ambler apparatus.

"Dehydration of Vegetables in the Union of South Africa," by G. M. Dreosti.

The Union dehydration industry is being actively developed and controlled by this office. A number of foods are being dehydrated in the Union, and new factories, new machinery and new products are continually being put into production. All the necessary machinery and equipment is made in the Union.

The vegetables are sorted and washed. Root vegetables are peeled by mechanical peelers and trimmed by hand. Root vegetables are then stripped or diced, and leafy vegetables are shredded. After cutting, the vegetables are blanched, primarily for inactivating enzymes, and are then spread on tinned gauze trays and dried to approximately 10 per cent. moisture content in a two-stage trolley-tunnel dryer. Drying to 5 per cent. moisture content is completed in a bin-dryer. The main advantages of a bin-dryer are ease of operation, convenience, reliability and economy. The dehydrated vegetables are packed straight from the bin-dryer into 4-gallon tins or A10 cans, from which the oxygen is removed by displacement with carbon dioxide. The South African gaspacking equipment, as also the vapour tension method of moisture content estimation of dehydrated vegetables, have not yet been published.

Roller dryers for milk have been successfully adapted for the drying of cooked mashed potato to form potato flakes for soups and stews, and for baking purposes. A modified spray dryer is being built for the production of potato mash powder, comprising small conglomerations of whole, unbroken potato cells. The product is reconstituted simply by the addition of hot water and stirring, and the resulting mash is undistinguishable from mash made from fresh cooked potatoes.

The main advances made in the dehydration of vegetables since the last War are (*a*) blanching primarily for inactivating enzymes; (*b*) rapid drying;

(*c*) reduction of moisture content from 10 per cent. to 5 per cent. and lower; (*d*) packing in hermetically sealed cans; and (*e*) gaspacking of vegetables.

A. J. H. Goodwin.
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 20, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of September 20, 1944, were passed.

Nomination to Membership:—R. L. de C. H. Saunders, proposed by M. R. Drennan, seconded by J. A. Keen.

Communications:—

"An Experimental Study of the Relation between Blood Haemoglobin Level and Nutritional State in School Children," by J. M. Latsky.

"Venous versus Capillary Blood: Is there a real Difference in Haemoglobin Content?" by J. M. Latsky.

"A Neutral Solution of Formaldehyde for Biological Purposes," by J. L. B. Smith.

A. J. H. Goodwin,
Hon. General Secretary.

The Annual Meeting of the Society was held on Wednesday, October 18, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The following were elected Fellows of the Society:—Robert Allen Dyer, D.Sc.; Norman Sapeika, Ph.D.; Lawrence Herbert Wells, M.Sc., M.B.

Among those present were Their Royal Highnesses Prince and Princess George of Greece and Prince Paul of Jugoslavia.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of September 20, 1944, were passed.

R. L. DE C. H. SAUNDERS was elected to Membership of the Society.

Communications:—

"The Effects of Medicinal Iron on the Blood of Anaemic and Normal European Children," by J. M. LATSKY.

"A Ground Axe from Natal," by C. VAN RIET LOWE.

"The Lower Beaufort (Karroo) Fauna of Southern Rhodesia," by G. BOND (communicated by A. J. H. GOODWIN).

Lecture:—

After a preliminary introduction by Miss M. BOYLE, the ABBÉ BREUIL outlined some aspects of the work on which he is at present engaged in the Cape.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 15, 1944, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 18, 1944, were passed, with the following addition:—The ABBÉ H. BREUIL and Dr. N. SAPEIKA were received as Fellows of the Society.

The following were nominated for Council for 1945:—

Officers:—President, A. BROWN; Secretary, A. J. H. GOODWIN; Treasurer, R. W. JAMES; Librarian, E. NEWBERY; Editor, A. L. DU TOIT.

Members:—J. JACKSON, J. G. ROSE, S. H. SKAIFE, C. L. WICHT, M. R. DRENNAN.

Additional Members:—J. V. L. RENNIE, P. J. DU TOIT, B. F. J. SCHÖNLAND, A. P. GOOSSENS.

Retiring Members:—H. G. FOURCADE, L. F. MAINGARD, E. P. PHILLIPS, J. SMEATH THOMAS.

The following were nominated to Membership of the Society:—

EDWARD BATSON, proposed by A. BROWN, seconded by A. L. DU TOIT; ALBERT RUDDOCK, proposed by J. V. L. RENNIE, seconded by D. BURNETT.

Communications:—

"Notes on the Distribution and Density of Population in Cape Town, 1936," by Edward Batson (communicated by A. J. H. Goodwin).

"Anthropometric Investigations carried out upon Physical Education Students of the University of Stellenbosch," by C. S. Grobbelaar.

"Blood Haemoglobin Standards for School Children in Normal Health and Nutrition," by J. M. Latsky.

"The Nutritional Significance of Low-normal versus High-normal Blood Haemoglobin," by J. M. Latsky.

Demonstration:—

"A Short Demonstration on Hearing in a Dog after the Removal of the Tympanic Membranes and the Malleus on both Sides," by C. S. Grobbelaar.

A. J. H. Goodwin,
Hon. General Secretary.

Report of the Hon. General Secretary for 1944.

Eight Ordinary Meetings, the Annual Meeting and the Anniversary Meeting were held during the year, and the following papers were read:—

1. "The Essential Oil of *Agathosma apiculata* Meyer," by J. L. B. Smith and D. E. A. Rivett.
2. "The Warm Springs of Loubad," by Leslie E. Kent.
3. "A Method for Estimating the Number of Random Groups of Adjacent Diseased Plants in a Homogeneous Field," by J. E. van der Plank (communicated by E. P. Phillips).
4. "A Universal Temperature Scale," by E. Newbery.
5. "A Time Reaction," by J. L. B. Smith.
6. "The Petrology of the Mount Arthur Dolerite Complex, East Griqualand," by A. Poldervaart (communicated by F. Walker).
7. "An Experimental Study of the Relation between Blood Haemoglobin Level and Nutritional State in School Children," by J. M. Latsky.
8. "Venous versus Capillary Blood: Is there a Real Difference in Haemoglobin Content?" by J. M. Latsky.
9. "A Neutral Solution of Formaldehyde for Biological Purposes," by J. L. B. Smith.
10. "The Effects of Medicinal Iron on the Blood of Anaemic and Normal European Children," by J. M. Latsky.
11. "A Ground Axe from Natal," by C. van Riet Lowe.
12. "The Lower Beaufort (Karroo) Fauna of Southern Rhodesia," by G. Bond (communicated by A. J. H. Goodwin).

13. "Notes on the Distribution and Density of Population in Cape Town, 1936," by EDWARD BATSON (communicated by A. J. H. GOODWIN).

14. "Anthopometric Investigations carried out upon Physical Education Students of the University of Stellenbosch," by C. S. GROBBELAAR.

15. "Blood Haemoglobin Standards for School Children in Normal Health and Nutrition," by J. M. LATSKY.

16. "The Nutritional Significance of Low-normal versus High-normal Blood Haemoglobin," by J. M. LATSKY.

Lectures:—

"Twenty Years of Archaeological Classification," by A. J. H. GOODWIN. Given at the Ordinary Meeting of the Society on 19th April.

At the Ordinary Meeting of the Society held on October 18, the ABBÉ BREUIL outlined some aspects of his archaeological work at the Cape.

Symposium:—

"Citrus By-products," by D. COGILL.

"Fruit Dehydration," by P. W. WISSING.

"Inspection of Dehydrated Vegetables," by D. J. DREYER.

"Dehydration of Vegetables in the Union of South Africa," by G. M. DREOSTI.

The above symposium was held at the Ordinary Meeting of the Society on 16th August.

Discussion:—

"The Invasion Area," by H. S. GRACIE, A. J. H. GOODWIN, W. K. SPENCER and F. WALKER. Held at the Ordinary Meeting of the Society on 21st June.

Demonstration:—

"Hearing in a Dog after the Removal of the Tympanic Membranes and the Malleus on both Sides," by C. S. GROBBELAAR. At the Ordinary Meeting of the Society on November 15.

General:—

ROBERT ALLEN DYER, NORMAN SAPEIKA and LAWRENCE HERBERT WELLS were elected Fellows of the Society in 1944.

At the end of 1944 the number of Fellows was 89, Members 116. During the year 6 new Members were elected and one Member resigned.

The death during the year of Professor J. T. MORRISON is recorded with regret.

The number of institutions, etc. on our exchange list is 220, of which 76 have ceased to exchange for the duration of the war.

Volume XXX, Part 2, of the Society's Transactions was issued during the year.

The thanks of the Council are due to the Union Government for a grant of £400 for the year 1944–45. The Council's thanks are due also to the University of Cape Town for a grant of £6, 10s. in aid of publishing a paper by E. NEWBERY.

The following gifts have been received by the Society during the year:—From Dr. C. L. WICHT, Two reprints; from A. J. H. GOODWIN, One reprint; from the Transvaal Museum, Fitzsimons: Lizards of South Africa, 1943; from the Librarian, University of Witwatersrand, FREER, P.: Catalogue of Union Periodicals, Vol. 1, 1943; from A. R. E. WALKER, Transactions of the Royal Society of S.A., Vol. 2 (complete).

The first award from the Marloth Memorial Fund was made in 1944 towards the cost of publication of the paper by J. L. B. SMITH and D. E. A. RIVETT entitled "The Essential Oil of *Agathosma*."

Eighty-seven periodicals were issued from the Society's Library in 1944, and a large number were also consulted in the Library.

A. J. H. GOODWIN,
Hon. General Secretary.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR JANUARY 1 TO DECEMBER 31, 1943.

DR.

	£ s. d.	£ s. d.
Bank Balance at January 1, 1942		58 0 4
Subscriptions:		
Up to 1941	18 5 0	
1942	30 0 0	
1943 (Fellows)	32 0 0	
1943 (Town Members)	28 0 0	
1943 (Country Members)	42 0 0	
1943 (Life Subscriptions)	75 0 0	
1943 (Entrance Fees)	10 19 8	
Advance Payments	3 6 0	
		239 10 8
Commission on cheques		1 1 6
Sales of publications		112 12 6
Sales of extra reprints		46 2 7
Grants:		
Union Government (Annual)	400 0 0	
University of Cape Town (Newberry; Walker and Poldervaart)	15 0 0	
University of the Witwatersrand (Wells, Malan and Cooke)	17 10 0	
Kenya Government (Leakey)	200 0 0	
		632 10 0
Interest:		
Rand Provident Building Society	14 0 0	
Good Hope Savings Bank (General) ...	12 12 8	
Good Hope Savings Bank (Life)	8 2 5	
Standard Bank Savings Bank	0 2 8	
Marloth Memorial Fund:		
Rand Provident Building Society	3 10 0	
United Building Society	3 10 0	
		41 17 9
		£1131 15 4

CR.

	£ s. d.	£ s. d.
Neill, Vols. XXIX, 3 and 4; XXX, 1:		
Printing	485 19 4	
Extra Reprints	45 4 8	
Postage and Charges	23 9 10	
		554 13 10
Local Printing		50 2 9
Clerical Assistance		45 0 0
Commission and Bank Charges		3 5 8
Petty Cash		15 10 0
Rent and Caretaker		80 8 0
Insurance		0 18 0
Miscellaneous:		
Photostats (Goetz)	2 14 6	
A. R. E. Walker (Trans., Vols. IX to XVIII)	4 0 0	
Rail and Shipping Charges	19 15 6	
Jones' Testimonial	2 10 0	
		29 0 0
Investment (Post Office Savings Bank)		200 0 0
Interest credited to Accounts:		
Good Hope Savings Bank (General) ...	12 12 8	
Good Hope Savings Bank (Life)	8 2 5	
Standard Bank Savings Bank	0 2 8	
		20 17 9
Bank Balance at January 1, 1944		131 19 4
		£1131 15 4

R. S. ADAMSON, } Hon. Auditors.
W. PUGH, }

R. W. JAMES, Hon. Treasurer.

ASSETS AND LIABILITIES AT DECEMBER 31, 1943.

Assets.*	£ s. d.	£ s. d.
Current Account Balance		131 19 4
Post Office Savings Bank		941 13 2
Standard Bank Savings Bank		7 18 5
Cape of Good Hope Savings Bank (General Fund)		374 12 5
Cape of Good Hope Savings Bank (Life Fund)		240 7 6
Rand Provident Building Society (Fixed Deposit)		400 0 0
Arrears of Subscriptions:		
Due in 1942	9 0 0	
Due in 1943	24 0 0	
		33 0 0
Arrears due for sales of Publications		2 8 8
Marloth Memorial Fund:		
Rand Provident Fixed Deposit	100 0 0	
United Building Society Fixed Deposit ...	100 0 0	
		200 0 0
		£2331 19 6

Liabilities.	£ s. d.	£ s. d.
Life Fund:		
Rand Provident Deposit	400 0 0	
Cape of Good Hope Savings Bank	240 7 6	
Current Account	34 3 6	
		674 11 0
Neill:		
Material in printers' hands (estimate) ...	650 0 0	
Additional Allowance	100 0 0	
		750 0 0
Binding Allocation		250 0 0
Advance Subscriptions		3 6 0
Marloth Fund:		
Capital	200 0 0	
Interest (1942)	6 10 0	
Interest (1943)	7 0 0	
		213 10 0
Excess of Assets over Liabilities		440 12 6
		£2331 19 6

* Exclusive of value of Library and Publications of the Society held in stock.

R. W. JAMES, Hon. Treasurer.

We hereby certify that we have examined the above Accounts of Revenue and Expenditure and of Assets and Liabilities, and compared them with the books, vouchers and other documents relative thereto, and that in our opinion these accounts set forth a correct description of the affairs of the Society.

R. S. ADAMSON,
W. PUGH, } Hon. Auditors.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR JANUARY 1 TO DECEMBER 31, 1944.

DR.	£ s. d.	£ s. d.
Bank Balance at January 1, 1944		131 19 4
Subscriptions:		
Up to 1942	4 0 0	
1943	10 0 4	
1944 (Fellows)	38 0 0	
1944 (Town Members)	22 0 0	
1944 (Country Members)	36 0 0	
1944 (Life Members)	36 0 0	
1944 (Entrance Fees)	7 0 0	
Advance Payments	6 1 0	
		159 1 4
Commission on cheques		1 3 3
Sales of publications		20 10 1
Sales of extra reprints		12 15 7
Grants:		
Union Government (Annual)	400 0 0	
University of Cape Town (Newbery) ...	6 10 0	
		406 10 0
Drawn from Post Office Savings Bank		100 0 0
Interest:		
Rand Provident Building Society	12 0 0	
Cape of Good Hope Savings Bank (General)	13 1 9	
Cape of Good Hope Savings Bank (Life)	8 8 0	
Post Office Savings Bank (1943 and 1944)	37 9 0	
Standard Bank Savings Bank	0 2 8	
Marloth Memorial Fund:		
Rand Provident Building Society ...	3 0 0	
United Building Society	3 0 0	
		77 1 5
		£909 1 0

CR.	£ s. d.	£ s. d.
Neill, Vol. XXX, 2:		
Printing	188 2 6	
Extra Reprints	20 13 0	
Postage and Charges	13 6 2	
Insurance (1941, 42, 43)	3 15 0	
		225 16 8
Local Printing		54 3 3
Clerical Assistance		56 0 0
Commission and Bank Charges		2 12 1
Rent and Caretaker:		
University of Cape Town (Library) ...	36 0 0	
South African Association (Rent)	4 4 0	
South African Association (Caretaker) ...	2 2 0	
		42 6 0
Insurance (Library)		0 18 0
Miscellaneous		5 19 3
Investment (Post Office Savings Bank)		400 0 0
Interest credited to Accounts:		
Post Office Savings Bank	37 9 0	
Good Hope Savings Bank (General Fund)	13 1 9	
Good Hope Savings Bank (Life Fund)	8 8 0	
Standard Bank Savings Bank	0 2 8	
		59 1 5
Bank Balance at January 1, 1945		62 4 4
		£909 1 0

R. S. ADAMSON, } Hon. Auditors.
W. PUGH, }

R. W. JAMES, Hon. Treasurer.

ASSETS AND LIABILITIES AT DECEMBER 31, 1944.

Assets.*	£ s. d.	£ s. d.
Current Account Balance		62 4 4
Post Office Savings Bank		1279 2 2
Standard Bank Savings Bank		8 1 1
Cape of Good Hope Savings Bank (General Fund)		387 14 2
Cape of Good Hope Savings Bank (Life Fund)		248 15 6
Rand Provident Building Society (Fixed Deposit)		400 0 0
Arrears of Subscriptions (1943 and 1944) ...		61 0 0
Marloth Memorial Fund:		
Rand Provident Fixed Deposit	100 0 0	
United Building Society Fixed Deposit ...	100 0 0	
		200 0 0
		£2446 17 3

Liabilities.	£ s. d.	£ s. d.
Life Fund		643 7 5
Neill:		
Material in Printers' Hands (Estimate) ...	650 0 0	
Additional Allowance	100 0 0	
		750 0 0
Allocation for Binding		300 0 0
Advance Subscriptions		6 1 0
Marloth Memorial Fund:		
Capital	200 0 0	
Interest (1942)	6 10 0	
Interest (1943)	7 0 0	
Interest (1944)	6 0 0	
		219 10 0
Excess of Assets over Liabilities		527 18 10
		£2446 17 3

* Exclusive of value of Library, Publications of the Society in stock, and other properties.

R. W. JAMES, Hon. Treasurer.

We hereby certify that we have examined the above Accounts of Revenue and Expenditure and of Assets and Liabilities, and compared them with the books, vouchers and other documents relative thereto, and that in our opinion these accounts set forth a correct description of the affairs of the Society.

R. S. ADAMSON,
W. PUGH, } Hon. Auditors.

MINUTES OF PROCEEDINGS.

Report of the Hon. General Secretary for 1945.

Eight Ordinary Meetings, the Annual Meeting and the Anniversary Meeting were held during the year, and the following papers were read:—

1. "Kinetics of Oxidation of Organic Compounds by Potassium Permanganate: VII. The Decomposition of Potassium Malonatodiaquomanganiate," by F. C. Tompkins.

2. "The Theory of Chromatography," by P. W. M. Jacobs, R. L. Rosenberg and F. C. Tompkins.

3. "The Essential Oil of *Agathosma gnidioides* Schl.," by J. L. B. Smith and D. G. Roux.

4. "*Stylocephalus ingeri* (sp. nov.): A Cephaline Gregarine found in the Gut of *Gonocephalum arenarium* (Coleoptera)," by Alfred J. Gibbs (communicated by H. Zwarenstein).

5. "The Behaviour of the F-region of the Ionosphere over Grahamstown during the Partial Solar Eclipse of January 14, 1945," by J. A. Gledhill and M. E. Szendrei (communicated by R. W. James).

6. "A Poisonous Alga from the Transvaal," by Edith Stephens.

7. "Some Remarks on the Biology of Reproduction in the Female of *Elephantulus*, the Holy Animal of Set," by C. J. van der Horst.

8. "Terraces in the Lower Part of the Sundays River Valley, Cape Province," by A. Ruddock.

9. "Some South African *Rhodophyceae*. II. *Helminthora Furcellata* (Tyson, ex Reinbold), comb. nov. *Nemalion Furcellatum* (Tyson, ex Reinbold)," by Margaret T. Martin (communicated by M. A. Pocock).

10. "*Chara rotunda* Stephens: A New South African Fossil Charophyte," by Leslie Kent and Edith L. Stephens.

11. "Two New Clinid Fishes from South Africa, with a Note on *Pomadasys olivaceum* Day," by J. L. B. Smith.

12. "The Development of the Striped Dogfish (Lui-Haai), *Poroderma africanum* Gmelin," by Cecil von Bonde.

13. "The Application of Pedological Methods to the Study of some Weathered Malmesbury Argillites of the Cape Peninsula," by Morna Mathias.

Lectures:—

"The Geology and Scenery of Madagascar," by F. WALKER. Given at the Ordinary Meeting of the Society on April 18.

"Antarctic Problems," by R. W. JAMES. Given at the Ordinary Meeting of the Society on June 20.

"Some Aspects of Science in the Recent War," by Commander B. L. GOODLET. Given at the Ordinary Meeting of the Society on October 17.

"Electrical Methods of Geophysical Prospecting," by R. GUELKE. Given at the Ordinary Meeting of the Society on November 21.

Demonstration:—

"Enzyme Destruction in Relation to Vegetable-Processing," by W. E. ISAAC. Held at the Ordinary Meeting of the Society on May 16.

Report:—

"Preservation of the Vegetation of the South Western Cape," by C. L. WICHT. Given at the Ordinary Meeting of the Society on March 21, 1945.

General:—

ALEXANDER JOHN BOYAZOGLU and BRIAN LAIDLAW GOODLET were elected Fellows of the Society in 1945.

At the end of 1945 the number of Fellows was 90, Members 117. During the year 6 new Members were elected and one Fellow resigned.

The deaths during the year of Dr. W. A. HUMPHREY, Dr. C. F. JURITZ and Dr. P. W. LAIDLER are recorded with regret.

In addition to Volume XXX, Part 2, of the Society's Transactions, Volume XXX, Part 3, was also published during 1944. During 1945 Volume XXX, Part 4, and Volume XXXI, Part 1, were published.

A special publication of the Society, "The Report of the Committee on the Preservation of the Vegetation of the South-Western Cape," edited by Dr. C. L. WICHT, was issued and circulated in August 1945, and copies were made available for sale to booksellers, libraries and other institutions.

The number of institutions, etc., on our exchange list at the end of 1945 was 223, of which 74 are still suspended owing to the war. Of the exchanges suspended for the duration, 2 were resumed during the year.

New exchanges were arranged with the following institutions:—

Bureau des Mines, Tananarive, Madagascar.

Colombo Museum, Pelmadulla, Ceylon.

Société d'Études Camerounaises, Douala, French Cameroons.

In August a cable of congratulations on the conclusion of the war was sent by the Society to His Majesty the King.

At the Ordinary Meeting of the Society on October 17 an amendment to the Statutes was passed, altering the annual subscription of local members to £1, and their compounding subscription to £15 less one-half of all annual

payments already made, with a minimum payment of £5. These alterations will come into force from March 1946.

The thanks of the Council are due to the Union Government for a grant of £400 for the year 1945–46. The Council's thanks are due also to Rhodes University College for a grant of £13 in aid of publishing papers by Messrs. GLEDHILL and SZENDREI, and Messrs. SMITH and ROUX, and to the University of Cape Town for a grant of £25 in aid of publishing papers by Mrs. MILLARD, and Messrs. WALKER and STEWART.

Gifts have been received by the Society during the year from the following sources:—Secreteriado Nacional da Informacao, Lisbon: Portugal, Nos. 79–87. Imperial Chemical Industries, London: Endeavour, Vol. 3, No. 12, and Vol. 4, Nos. 14–16. Universidad de Buenos Aires: Revista de la Universidad de Buenos Aires, 1944–45. Institute of Medical and Veterinary Science, South Australia: Seventh Annual Report, 1944–45, and Collected Papers, Vol. 2, 1941–44. Africana Museum, Johannesburg: Annual Report for year ended 30th June 1945. Minister of Agriculture, Canada: Report for year ended March 1944. Association des Ingénieurs de la Faculté Technique du Hainaut a Mons: La Recherche Scientifique au Congo Belge, No. 9, 1945. Sociedade Geologica de Portugal: Bulletin, Vol. 4, Fasc. 3, 1945. Welsh Agricultural Conference: Welsh Journal of Agriculture, Vol. 28, 1945. Academia Brasileira de Ciencias: Anais da Academia Brasileira de Ciencias, Vol. 26, Nos. 3 and 4. A. H. WALLIS: Physics of the Earth, Vol. 8: Terrestrial Magnetism and Electricity. Kaffrarian Museum: Report presented at the annual meeting of subscribers, March 1945. Dr. F. GORDON CAWSTON: A Study of the Dentitions of Selachians, Reptiles and Some Other Animals (in pamphlet form).

Also received as gifts were two copies each of Portugal and the Peace (speeches by the President of the Council), and Mocidade Portuguesa, as well as a number of Russian scientific publications.

A large number of back numbers of the Transactions of the Society was received during the year from Professor H. H. PAINE and Dr. E. C. HALLIDAY.

One hundred and twenty-five periodicals and 9 books were issued from the Society's Library during 1945.

A. J. H. GOODWIN,
Hon. General Secretary.

ANNIVERSARY MEETING.

The Anniversary Meeting of the Society was held on Wednesday, March 21, 1945, at 8 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Report of the Hon. General Secretary for 1944 was read and passed.

The Report of the Hon. Treasurer for 1944 was read and passed.

The following were duly elected as Officers and Council for 1945:— President, A. BROWN; Treasurer, R. W. JAMES; Secretary, A. J. H. GOODWIN; Editor of Transactions, A. L. DU TOIT; Librarian, E. NEWBERY; Members of Council: J. JACKSON, J. G. ROSE, S. H. SKAIFE, C. L. WICHT, M. R. DRENNAN, J. V. L. RENNIE, P. J. DU TOIT, B. F. J. SCHÖNLAND, A. P. GOOSSENS.

ORDINARY MEETING.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

After the deletion of the name M. R. DRENNAN from the list of Additional Members of Council, the Minutes of the Ordinary Meeting of November 15, 1944, were passed.

EDWARD BATSON and ALBERT RUDDOCK were elected to Membership of the Society.

Communications:—

"Kinetics of Oxidation of Organic Compounds by Potassium Permanganate: VII. The Decomposition of Potassium Malonatodiaquomanganiate," by F. C. TOMPKINS.

The decomposition has been studied in aqueous solution and has been shown to be mono-molecular with respect to the loss of oxidising power. The rate was found to be directly proportional to the hydrogen ion concentration and inversely to the concentration of malonic acid molecules; the addition of neutral salts caused a retardation, indicating that the rate-determining reaction was due to collisions between oppositely charged univalent ions. The heat of activation is calculated to be 19,500 cals. per gm. mol. A mechanism has been proposed which is in accord with the experimental rate equations and which is also applicable to the decomposition of the corresponding oxalato-complex in this, the rate-determining reaction is the addition of a proton to the complex, thereby inducing the dissociation of the aquo-ion into the corresponding hydroxo-ion.

"The Theory of Chromatography," by P. W. M. JACOBS, R. L. ROSENBERG and F. C. TOMPKINS.

The differential equation, originally set up by Wilson, to describe chromatographic adsorption processes in columns has been examined, and it has been shown that the only possible solutions are those which lead to an increasing sharpness of the leading edge of the band, both on develop-

ment and on formation, when the isotherm is of the normal type, and that this is not in agreement with the available experimental data. The importance of the hydrodynamical effect, due to the turbulence of flow through the interstices of the adsorbent, has been emphasised, and has here been introduced into the previous equation and solved in the case of a linear isotherm. The solution of this modified differential equation gives the main characteristics of the concentration distribution found experimentally. The magnitude of the turbulent diffusion constant has been calculated and the value appears to be of reasonable magnitude.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 18, 1945, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of March 21, 1945, were passed.

The following were nominated to Membership of the Society:—Hedley Brian Rycroft, nominated by C. L. Wicht, seconded by A. J. H. Goodwin. Edward Kendal Marsh, nominated by C. L. Wicht, seconded by A. J. H. Goodwin. Keith Jolly, nominated by A. Brown, seconded by A. L. du Toit.

Communications:—

"The Essential Oil of *Agathosma gnidioides* Schl.," by J. L. B. Smith and D. G. Roux.

"*Stylocephalus ingeri* (sp. nov.): A Cephaline Gregarine found in the Gut of *Gonocephalum arenarium* (Coleoptera)," by Alfred J. Gibbs (communicated by H. Zwarenstein).

Lecture:—

"The Geology and Scenery of Madagascar," by F. Walker.

The basic structure and overlying formations of the island have been tilted. These factors, together with the high rainfall prevalent over a great part of Madagascar and the tendency for the soil to erode and to form a silica-free laterite, have all had marked effects on the typical scenery. This has been further affected by native agricultural methods in paddy-fields and forest-clearings, and by the swift run-off of the river system, which is intimately bound up with the trellis pattern formed by marked North-South mountain systems and valleys that have to be negotiated

before the sea is reached. Only a narrow shelf is left on the eastern side of the island, along which primitive canal and lagoon navigation provides purely local transport.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 16, 1945, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of April 18, 1945, were read and passed.

The President drew the attention of the Meeting to the death of Dr. F. C. JURITZ, at the age of eighty-one, and referred to his scientific research, his Fellowship of the Society, and his valuable assistance to the South African Association for the Advancement of Science. Those present paid tribute to his memory.

The following were elected to Membership of the Society:—KEITH JOLLY, EDWARD KENDAL MARSH and HEDLEY BRIAN RYCROFT.

Communications:—

"The Behaviour of the F-region of the Ionosphere over Grahamstown during the Partial Solar Eclipse of January 14, 1945," by J. A. GLEDHILL and M. E. SZENDREI (communicated by R. W. JAMES).

"*Microcystis toxica* (sp. nov.): A Poisonous Alga from the Transvaal and Orange Free State," by EDITH STEPHENS.

Demonstration:—

"Enzyme Destructjon in Relation to Vegetable-Processing," by W. E. ISAAC.

Processed vegetable products are essentially similar to the cooked or partially cooked vegetables from which they are made. Canned, frozen and dehydrated products are the most important processed vegetable products.

The temperature conditions involved in canning are such as to eliminate residual enzyme activity although pre-cooking or blanching may be necessary —*inter alia*, for enzyme destruction in some plant products. For frozen and dehydrated vegetables, the control of enzyme destruction is of considerable importance.

Little information is available regarding the activity of specific enzymes

in relation to deterioration. Thus the efficiency of blanching is judged by testing its effect on an indicator enzyme. Such an enzyme must be widely distributed and must not be too easily destroyed by heat. The enzyme which is now usually chosen is peroxidase.

The presence of peroxidase is indicated by the development of the appropriate colour when hydrogen peroxide and a suitable substrate are added to tissue or tissue extract. Over 40 substances are listed which can be used for this purpose but for various reasons they are of different value. In general, guaiacol would seem to be the most suitable.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 20, 1945, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of May 16, 1945, were passed.

Communication:—

"Some Remarks on the Biology of Reproduction in the Female of *Elephantulus*, the Holy Animal of Set," by C. J. van der Horst.

Lecture:—

"Antarctic Problems," by R. W. James.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 15, 1945, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of June 20, 1945, were passed.

The President announced the following nominations for election to Fellowship of the Society for 1945:—Alexander John Boyazoglu (for outstanding work in agricultural research, including rural economic surveys and allied investigations carried out in South Africa, and in Greece, Poland, Jugoslavia, etc.), proposed by R. A. Dart, J. F. V. Phillips, H. H. Paine, C. J. van der Horst, H. R. Raikes and L. F. Maingard.

Brian Laidlaw Goodlet (for outstanding research in electrical engineering, both under conditions of peace and in association with the Royal Navy), proposed by R. S. Adamson, F. Walker, H. A. Reyburn and L. C. Young.

The Annual Meeting for the election of Fellows will be held on Wednesday, October 17, 1945.

The President read a cable addressed to His Majesty the King, from the Society:—

"We respectfully offer most joyful congratulations on the final victory of Your Majesty's forces by sea, land and air."

Colin Romney Gohl was nominated for election to Membership of the Society, proposed by C. L. Wicht, seconded by A. Ogg.

The President gave notice that at a meeting of Council held on Tuesday, May 29, 1945, the Treasurer had proposed the following motion: "That in future there shall be no differentiation between Members resident within and outside the twenty-five-mile radius from Cape Town." This was seconded by E. Newbery, and passed by Council. The motion will be discussed at the Ordinary Meeting following the Annual Meeting on October 17. Should any Member or Fellow desire to express an opinion, he is invited to do so in writing to the Hon. General Secretary, or verbally at the meeting.

The following alterations to existing Statutes are envisaged:—

Chap. IV. 1. Par. (i) to read, "Every Member shall pay the subscription of one pound annually in advance so long as he shall continue a Member of the Society."

Chap. IV. 2. Par. (i) to read, "A Fellow may compound . . . etc."
(ii) to read, "A Member may compound . . . etc."
(iii) to read, "Provided that any such Member who shall subsequently be elected a Fellow . . . etc."

The President announced the publication of the Report on "The Preservation of the Vegetation of the South-Western Cape," by C. L. Wicht. Copies of this special publication of the Society will be distributed to Members and Fellows in due course.

Communications:—

"Terraces in the Lower Part of the Sundays River Valley, Cape Province," by A. Ruddock.

"Some South African *Rhodophyceae*. II. *Helminthora Furcellata* (Tyson, ex Reinbold), comb. nov. *Nemalion Furcellatum* (Tyson, ex Reinbold)," by Margaret T. Martin (communicated by M. A. Pocock).

Members and Fellows are reminded that copies of unneeded parts of the Transactions are still wanted for the bombed cities of Europe.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 19, 1945, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

Dr. A. L. du Toit was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of August 15 were passed.

The President apologised for his inability to attend.

The Chairman drew the attention of the Meeting to the death of Dr. P. W. Laidler, at Stellenbosch, at the age of fifty-nine, on September 3. Dr. Laidler was a Member of the Society.

C. R. Gohl was elected to Membership of the Society.

Communications:—

"*Chara rotunda* Stephens: A New South African Fossil Charophyte," by Leslie Kent and Edith L. Stephens.

"Two New Clinid Fishes from South Africa, with a Note on *Pomadasys olivaceum* Day," by J. L. B. Smith.

"The Development of the Striped Dogfish (Lui-Haai), *Poroderma africanum* Gmelin," by Cecil von Bonde.

A. J. H. Goodwin,
Hon. General Secretary.

Annual Meeting.

The Annual Meeting of the Society was held on Wednesday, October 17, 1945, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

Alexander John Boyazoglu and Brian Laidlaw Goodlet were elected Fellows of the Society.

Commander Goodlet was admitted to Fellowship.

Ordinary Meeting.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of September 19, 1945, were passed.

The Treasurer proposed the following amendment to the Statutes: "That in future there shall be no differentiation between Members resident

within and outside the twenty-five-mile radius from Cape Town." This was duly seconded by E. NEWBERY, and passed by the Meeting.

The consequent changes in Chapter IV, clauses 1 and 2, of the Statutes of the Society are therefore announced:—

"1. Every Member shall pay the subscription of one pound annually in advance, so long as he shall continue a Member of the Society.

"Every Ordinary Fellow shall pay the subscription of two pounds annually in advance, so long as he shall continue a Fellow of the Society.

"Annual subscriptions are due on the first day of January of each year.

"2. A Fellow may compound for the future annual subscriptions by a single payment of twenty-five pounds, less one-half of all annual payments already made by him to the Society. The minimum compounding payment shall be five pounds.

"A Member may compound for the future annual subscriptions by a single payment of fifteen pounds, less one-half of all annual payments already made by him to the Society. The minimum compounding payment shall be five pounds.

"Any such Member who shall subsequently be elected a Fellow of the Society shall make either an additional annual payment of one pound, or an additional compounding payment of ten pounds, less half the additional annual payments made. The minimum additional compounding payment shall be five pounds.

"Any cases which are not covered by this Statute shall be determined by Council."

The remainder of the Chapter will remain unaltered. These alterations will come into force covering the 1946 subscriptions.

Lecture:—

"Some Aspects of Science in the Recent War," by Commander B. L. GOODLET.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 21, 1945, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. BROWN, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 17, 1945, were read and passed.

The names for election to Council, 1946, were announced.

William Francis Barker was admitted to Fellowship.

Ronald Gordon Shuttleworth was nominated to Membership, proposed by E. Newbery, seconded by A. J. H. Goodwin.

Communication:—

"The Application of Pedological Methods to the Study of some Weathered Malmesbury Argillites of the Cape Peninsula," by Morna Mathias.

Lecture:—

"Electrical Methods of Geophysical Prospecting," by R. Guelke.

A. J. H. Goodwin,
Hon. General Secretary.

Anniversary Meeting.

The Anniversary Meeting of the Society was held at 8.15 p.m. on Wednesday, March 20, 1946, in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor A. Brown, was in the Chair.

Business:—

The Report of the Hon. General Secretary for 1945 was read and passed.

The Report of the Hon. Treasurer for 1945 was read and passed.

The following were duly elected as Officers and Council for 1946:— President, R. S. Adamson; Secretary, A. J. H. Goodwin; Treasurer, R. W. James; Librarian, E. Newbery; Editor of Transactions, A. L. du Toit. Members of Council: D. Burnett, P. J. du Toit, B. L. Goodlet, A. P. Goossens, J. Jackson, J. G. Rose, I. Schapera, B. F. J. Schonland, F. Walker, C. L. Wicht.

Ordinary Meeting.

The Anniversary Meeting was followed by an Ordinary Meeting.

The President, Professor R. S. Adamson, took the Chair.

Business:—

The Minutes of the Ordinary Meeting of November 21, 1945, were passed.

The President announced the death of Dr. H. E. Wood, for many years Union Astronomer, and a Fellow of this Society.

The President read a letter from the Cape School Board, refusing with

regret the application of the Society for the use of Rustenburg School Hall for future meetings.

RONALD GORDON SHUTTLEWORTH was elected to Membership.

The following were nominated for Membership of the Society:—

Miss D. L. OLIVIER, Miss M. S. LE ROUX and S. GARSIDE, proposed by R. S. ADAMSON, seconded by M. LEVYNS.

A. G. HALES and MARTIN JOHN POLLARD, proposed by A. BROWN, seconded by R. S. ADAMSON.

G. MORTELMANS, proposed by C. VAN RIET LOWE, seconded by A. J. H. GOODWIN.

JAMES G. TAYLOR, proposed by A. J. H. GOODWIN, seconded by R. S. ADAMSON.

ANDRIES WILLEM LATEGAN, LIONEL GORFINKEL and FELIX SEBBA, proposed by E. NEWBERY, seconded by A. J. H. GOODWIN.

A. G. STAGMAN and GAVIN T. LAMONT, proposed by F. WALKER, seconded by A. J. H. GOODWIN.

Communications:—

"A Preliminary Investigation of the General Biology of the South African Hake or Stockfish," by E. R. ROUX.

"On a New Genus of Fishes of the Family Creediidae from South Africa, with Remarks on its General Distribution," by L. F. DE BEAUFORT (communicated by C. J. VAN DER HORST).

"Observations on the Origin of Teeth in Fishes," by F. GORDON CAWSTON.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 17, 1946, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor R. S. ADAMSON, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of March 20, 1946, were passed.

A vote of thanks was accorded to Professor ALEXANDER BROWN, retiring President.

The following were elected to Membership of the Society:—S. GARSIDE, L. GORFINKEL, A. G. HALES, G. T. LAMONT, A. W. LATEGAN, Miss M. S. LE ROUX, G. MORTELMANS, Miss D. L. OLIVIER, M. J. POLLARD, F. SEBBA, A. G. STAGMAN, J. G. TAYLOR.

The following was nominated to Membership of the Society:—NAOMI A. H. MILLARD, proposed by H. SANDON, seconded by A. BROWN.

Matters concerning the Library of the Royal Society, housed in the Jagger Library, University of Cape Town, Rondebosch, were raised, and Mr. IMMELMAN, the University Librarian, spoke. The suggestions placed before a meeting of Council in March 1946 were accepted by the Meeting.

Communication:—

"A Statistically Designed Experiment to Test the Effects of Burning on a Sclerophyll Scrub Community: I. Preliminary Account," by C. L. WICHT.

Lecture:—

"Soil Erosion Survey of the Western Cape Province," by W. J. TALBOT.

The lecturer gave a résumé of personal research undertaken in the Western Cape, and supported a strong case with a series of excellent lantern slides.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 15, 1946, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor R. S. ADAMSON, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of April 17 were passed.

NAOMI A. H. MILLARD was elected to Membership of the Society.

The following were nominated to Membership of the Society:—R. I. G. ATTWELL, E. TABENER and I. J. M. WILLIAMS, all proposed by E. NEWBERY and seconded by R. SMITHERS.

Communication:—

"The Fossil Suina of South Africa," by H. B. S. COOKE.

Lecture:—

"Wind-faceted Stones from Robberg, Plettenberg Bay," by L. C. KING.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 19, 1946, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor R. S. ADAMSON, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of May 15, 1946, were passed.

R. I. G. ATTWELL, E. TABENER and I. J. M. WILLIAMS were elected to Membership.

Nominations to Membership:—

D. H. S. HORN, proposed by E. NEWBERY, seconded by A. J. H. GOODWIN.

J. M. VISSER, proposed by E. NEWBERY, seconded by A. J. H. GOODWIN.

Lecture:—

"Our Friendly Bacteria and Yeasts," by A. W. LATEGAN.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 21, 1946, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor R. S. ADAMSON, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of June 19, 1946, were passed.

D. H. S. HORN and J. M. VISSER were elected to Membership.

The following were nominated for election to Membership of the Society:—C. R. HEARD, proposed by M. R. LEVYNS, seconded by R. S. ADAMSON. CLEMENT W. ABBOTT, proposed by M. WILMAN, seconded by A. L. DU TOIT. N. SHAND, proposed by J. G. ROSE, seconded by E. NEWBERY.

The President announced the following nominations for election to Fellowship of the Society:—HERBERT BASIL SUTTON COOKE, M.A., M.Sc., proposed by R. A. DART, A. GALLOWAY, C. VAN RIET LOWE and A. W. ROGERS. WILLIAM EDWYN ISAAC, B.Sc., Ph.D., proposed by W. PUGH, A. BROWN, L. BOLUS and M. R. LEVYNS. LESLIE ERROL KENT, M.Sc., proposed by A. W. ROGERS, S. H. HAUGHTON, C. VAN RIET LOWE and E. L. GILL. WILLIAM SAGE RAPSON, M.Sc., D.Phil., A.R.I.C., proposed by M. R. LEVYNS, W. PUGH, R. W. JAMES, A. BROWN and B. L. GOODLET.

Lecture:—

"Some Research Contributions to Organic Chemistry," by R. G. SHUTTLEWORTH.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 18, 1946, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor R. S. ADAMSON, was in the Chair.

Business:—

With the addition of two nominations for election to Membership—E. G. MANKEN and F. J. LEWY, both proposed by J. G. ROSE and seconded by E. NEWBERY—the Minutes of the Ordinary Meeting of August 21, 1946, were passed.

The President expressed the regret of the Society at the death of Sir J. CARRUTHERS BEATTIE, one time President of the South African Philosophical Society, and first Principal of the University of Cape Town.

The following were duly elected to Membership of the Society:—C. R. HEARD, CLEMENT W. ABBOTT, N. SHAND, E. G. MANKEN and F. J. LEWY.

The following were nominated for election to Membership of the Society:—W. E. SCHILZ, proposed by J. S. VAN DER LINGEN, seconded by A. BROWN. J. H. O. DAY, proposed by H. SANDON, seconded by E. NEWBERY.

The President announced that Council wishes to draw the attention of Members and Fellows to the fact that, as from 1947, the award of the Marloth medallion for the best chemical or botanical paper submitted will be considered in March and in August in each year.

An award will only be made if papers received are of sufficiently high standard. The medallion will be printed at the head of the successful paper.

Lecture:—

"The Care and Preservation of Books and Documents," by D. H. VARLEY.

A. J. H. GOODWIN.
Hon. General Secretary.

Annual Meeting.

The Annual Meeting of the Society was held on Wednesday, October 16, 1946, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor R. S. Adamson, was in the Chair.

Business:—

The following were elected to Fellowship of the Society:—Herbert Basil Sutton Cooke, M.A., M.Sc.; William Edwyn Isaac, B.Sc., Ph.D.; Leslie Errol Kent, M.Sc.; William Sage Rapson, M.Sc., D.Phil., A.R.I.C.

W. E. Isaac and W. S. Rapson were admitted to Fellowship of the Society.

Ordinary Meeting.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of September 18, 1946, were passed.

The Obituary of Sir J. Carruthers Beattie was read.

W. E. Schilz and J. H. O. Day were elected to Membership.

Communications:—

"The Experimental Production of Gastric Erosion in *Xenopus laevis*," by W. Beck, L. Mirvish and H. Zwarenstein.

1. Ligatured stomachs filled with acids of varying strengths and suspended in warm Ringer's solution undergo perforation in an area mainly localised to the proximal third of the lesser curvature of the stomach.

2. The time taken for perforation varies with the strength of the acid and the temperature of the Ringer's. There were no seasonal variations and starvation had no effect.

3. Perforation also occurs in the ligatured duodenum filled with acid and pepsin but not when the duodenum is filled with acid alone.

4. Perforation is due to the digestive action of acid and pepsin on the gastro-intestinal wall.

"Neolithic Stone Implements, Bamenda, British Cameroons," by M. D. W. Jeffreys.

This article describes some types of stone implements found by the author in the British Cameroons in the years 1936–45.

The writer contends that though these implements fall into the category of the flaked core, they are neolithic in origin and not palaeolithic, as has

been stated by others. The materials used and the flora of the terrain as affecting their age are described. The earlier accounts of the discoveries and records of recent use of stone implements on the west coast of Africa is summarised, and finally a brief description is given of the specimens illustrated with the possible ways of hafting them.

Lecture:—

"The Study of Thermal Vibrations in Crystals by Means of X-rays," by R. W. JAMES.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 20, 1946, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Professor R. S. ADAMSON, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 16, 1946, were passed.

The following were nominated to Membership of the Society:—A. M. DE VILLIERS, proposed by C. L. WICHT, seconded by H. B. RYCROFT. C. JACOBSZ, proposed by J. S. VAN DER LINGEN, seconded by A. BROWN. P. L. M. LE ROUX, proposed by R. W. JAMES, seconded by A. OGG. S. P. SHERRY, proposed by C. L. WICHT, seconded by H. B. RYCROFT.

Honorary Fellowship:—

In view of the lifelong devotion of Dr. ROBERT BROOM, F.R.S., to the cause of science in general and to South African palaeontology in particular, Council has decided to nominate him as an Honorary Fellow of the Society. The nomination has been proposed by the following Officers of the Society: R. S. ADAMSON, President; E. NEWBERY, A. L. DU TOIT, A. J. H. GOODWIN, J. G. ROSE and F. WALKER. The election will take place at the Ordinary Meeting of the Society to be held on March 19, 1947.

Council, 1947:—

President, Professor R. S. ADAMSON; Secretary, A. J. H. GOODWIN; Treasurer, J. G. ROSE; Editor, A. L. DU TOIT; Librarian, E. NEWBERY.

Members of Council: *M. R. DRENNAN, P. J. DU TOIT, *W. E. ISAAC, J. JACKSON, R. W. JAMES, *R. F. LAWRENCE, *J. V. L. RENNIE, B. F. J. SCHONLAND, F. WALKER, C. L. WICHT.

(Retiring Members: D. BURNETT, B. GOODLET, A. P. GOOSSENS and I. SCHAPERA.)

* Refers to additional Members.

Communications:—

"A Report on the Culture of the South African Clawed Frog, *Xenopus laevis* (Daudin.), at the Jonkershoek Inland Fish Hatchery," by D. Hey.

"The Fertility of the Brown Trout Ova (*Salmo fario*) at the Jonkershoek Inland Fish Hatchery," by D. Hey.

This paper covers the findings of ten years of research on the problem of the low fertility of Brown Trout ova (*Salmo fario*) at the Jonkershoek Inland Fish Hatchery, Stellenbosch.

The investigation was commenced on the artificial factors such as stripping, hatching-house technique and diet. Thereafter both the male and female stock fish were thoroughly examined, and finally as complete a record as possible was obtained of climatic conditions at Jonkershoek as compared with other trout waters. The more important findings of this investigation were that:—

(1) The fertility of the ova was raised by a modification in stripping technique.

(2) There is a period of optimum fertility at which stage the eggs should be stripped. Eggs stripped prior to this period may be infertile due to under-ripeness, whereas those stripped after may be overripe.

(3) The maximum mortality in any one batch of eggs can be expected on the ninth day after impregnation.

(4) The genital system of the male is normal and the effective life of the milt in water does not exceed 40 seconds.

(5) The genital system of the female appears to be normal.

(6) By improving the diet and regular feeding, the stock fish have gained in condition, the yield of ova has been raised, and the eggs strip with ease.

(7) While ecological factors such as streamflow and temperature are by no means optimum, none of the factors investigated presents a definite obstacle to the culture of trout.

Although an improvement in the fertility of the eggs and general condition of the breeders has been brought about, the problem of the low fertility of the Brown Trout ova at this hatchery has by no means been solved. While the mean is just over 80 per cent., the fertilities of individual batches vary. Not infrequently fertilities of 98 per cent. have been recorded, which leads one to hope that it will become possible to raise the general standard to this level.

"Studies of South African Seaweed Vegetation. II. South Coast: Rooi Els to Gansbaai, with Special Reference to Gansbaai," by W. E. Isaac.

"Fossil Bovidae from the Makapan Valley Lime Deposits, Potgietersrust," by L. H. Wells.

The material described in this paper has been collected from several different horizons in three quarries in the Makapan Valley. It includes at least twenty species, all of which are referred to known genera. Eight species are described as new: *Antidorcas magnus, Gazella vanhoepeni, Gazella* (?) *gracilior, Oreotragus major, Raphicerus* (?) *pachygnathus, Sylvicapra* (?) *fragmentalis, Tragelaphus broomi, Tragelaphus oreades*. Several other forms not at present distinguishable from human species may prove to be extinct when more complete material is available. A provisional list of other animal types identified from these deposits is available. From the fauna it is concluded that the deposits cover the Early and part of the Middle Pleistocene, and may extend back into the concluding phases of the Late Pliocene.

"A Note on the Immediate Effects of Veldburning on Stormflow in a Jonkershoek Stream Catchment," by H. B. Rycroft.

An investigation carried out in a Jonkershoek stream catchment to examine the effects of autumn burning of veld on stormflow the following winter showed that there was:—

(1) A highly significant increase in the rate of stormflow.

(2) A rise in flood heights.

(3) An increase in the volume of stormflow.

(4) An increase in total stream discharge.

These conclusions indicate that there is a serious danger of flooding and erosion if the protective vegetation is removed by late autumn burning.

A. J. H. Goodwin,
Hon. General Secretary.

Report of the Hon. General Secretary for 1946.

Eight Ordinary Meetings, the Annual Meeting and the Anniversary Meeting were held during the year, and the following papers were read:—

1. "A Preliminary Investigation of the General Biology of the South African Hake or Stockfish," by E. R. Roux.

2. "On a New Genus of Fishes of the Family Creediidae from South Africa, with Remarks on its General Distribution," by L. F. de Beaufort (communicated by C. J. van der Horst).

3. "Observations on the Origin of Teeth in Fishes," by F. Gordon Cawston.

4. "A Statistically Designed Experiment to Test the Effects of Burning on a Sclerophyll Scrub Community: I. Preliminary Account," by C. L. Wicht.

5. "The Fossil Suina of South Africa," by H. B. S. COOKE.

6. "The Experimental Production of Gastric Erosion in *Xenopus laevis*," by W. BECK, L. MIRVISH and H. ZWARENSTEIN.

7. "Neolithic Stone Implements, Bamenda, British Cameroons," by M. D. W. JEFFREYS.

8. "A Preliminary Report on the Culture of the South African Clawed Frog, *Xenopus laevis* (Daudin.), at the Jonkershoek Inland Fish Hatchery," by D. HEY.

9. "The Fertility of the Brown Trout Ova (*Salma fario*) at the Jonkershoek Inland Fish Hatchery," by D. HEY.

10. "Studies of South African Seaweed Vegetation. II. South Coast: Rooi Els to Gansbaai, with Special Reference to Gansbaai," by W. E. ISAAC.

11. "Fossil Bovidae from the Makapan Valley Lime Deposits, Potgietersrust," by L. H. WELLS.

12. "A Note on the Immediate Effects of Veldburning on Stormflow in a Jonkershoek Stream Catchment," by H. B. RYCROFT.

Lectures:—

"Soil Erosion Survey of the Western Cape Province," by W. J. TALBOT. Given at the Ordinary Meeting of the Society on April 17.

"Wind-Faceted Stones from Robberg, Plettenberg Bay," by L. O. KING. Given at the Ordinary Meeting of the Society on May 15.

"Our Friendly Bacteria and Yeasts," by A. W. LATEGAN. Given at the Ordinary Meeting of the Society on June 19.

"Some Research Contributions to Organic Chemistry," by R. G. SHUTTLEWORTH. Given at the Ordinary Meeting of the Society on August 21.

"The Care and Preservation of Books and Documents," by D. H. VARLEY. Given at the Ordinary Meeting of the Society on September 18.

"The Study of Thermal Vibrations in Crystals by Means of X-rays," by R. W. JAMES. Given at the Ordinary Meeting of the Society on October 16.

The thanks of the Society are due to the Lecturers.

General:—

HERBERT BASIL SUTTON COOKE, WILLIAM EDWYN ISAAC, LESLIE ERROL KENT and WILLIAM SAGE RAPSON were elected Fellows of the Society in 1946.

At the end of 1946 the number of Fellows was 92, Members 141. During the year 26 new Members were elected and one Member resigned.

The deaths of Professor C. E. LEWIS, Mr. A. H. WALLIS, Dr. H. E. WOOD, Dr. A. W. ROGERS and Sir J. CARRUTHERS BEATTIE are recorded with regret.

Parts 2 and 3 of Vol. XXXI of the Society's Transactions were published

during the year. In 1946 the Transactions of the Society were sent to 237 institutions. Of the exchanges suspended owing to the war, 6 were resumed, and 56 were still suspended at the end of the year. New exchanges were arranged with the following:—Direccao Geral de Minas e Servicos Geologicos, Porto, Portugal. Instituto de Botanico Darwinion, San Isidro, Buenos Aires. Queen Victoria Museum, Launceston, Tasmania. Rothamsted Experimental Station, Harpenden, Herts. University of Pavia, Italy. Geological Survey, Southern Rhodesia.

The thanks of the Council are due to the Union Government for a grant of £400 for the year 1946–47. The Council's thanks are due also to Mrs. A. E. F. Selfe for a grant in aid of publication.

The Society received gifts during the year from the following:—

Dr. M. D. W. Jeffreys. Reprints of four articles.

Biological Abstracts, Philadelphia. Report for 1945.

Salazar Says. To Vote is a Great Duty.

Luiz Teixeira. Collaborating Neutrality.

Instituto Botanico da Faculdade de Ciencias, Lisboa. Portugaliae Acta. Biologica. Series A, v. 1, Nos. 1 and 2; Series B, v. 1, Nos. 1 and 2.

B. C. Templeton. Nomen conservandum for the genus Aromia.

Secretariado Nacional da Informacao. Social Assistance in Portugal.

Chinese-American Institute of Cultural Relations. Quarterly Bulletin of Chinese Bibliography, v. 5, 1945, Nos. 1–4.

G. E. Brausch. Groepethnologie de maatschappelijke groep als scheppende synthese.

Union of South Africa. Inland Fisheries Dept. Report No. 2 (1945).

Dr. F. G. Cawston. Schistosomiasis in Southern Africa.

S.A.C.S.I.R. National Building Research Institute.

Unesco. Tasks and Functions of the Division of Natural Sciences.

W. Proctor. Biological Survey of the Mount Desert Region: The Insect Fauna.

Union of South Africa. Dept. of Commerce and Industries. Building Research.

A portion of the valuable library of the late Dr. A. W. Rogers was received from Mrs. Rogers; this is largely geological and is housed with other volumes of the Society.

An almost complete set of the Transactions of the Society was received from Professor A. Ogg, several volumes of the Transactions were donated by Dr. D. J. Malan, and some parts were given by Professor I. Schapera.

Drs. Jackson, Schonland and Professor Smeath Thomas attended the Newton Tercentenary Celebrations in London.

Professor R. W. James is acting as correspondent with Clarendon

Laboratory, Oxford, on the question of ensuring that atomic energy is employed for peaceful purposes only.

The Marloth Memorial Award, with medallion, was made to Dr. C. L. WICHT.

The Society has undertaken to publish a Memorial Volume to Dr. ROBERT BROOM in honour of his eightieth birthday.

One hundred and six periodicals and 22 books were issued from the Society's Library during 1946.

A. J. H. GOODWIN,
Hon. General Secretary.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR JANUARY 1 TO DECEMBER 31, 1945.

DR.

	£ s. d.	£ s. d.
Bank Balance at January 1, 1945		62 4 4
Subscriptions:		
Up to 1943	8 0 0	
1944	17 0 0	
1945 (Fellows)	33 0 0	
1945 (Town Members)	22 0 0	
1945 (Country Members)	47 0 0	
1945 (Life Subscribers)	5 0 0	
Entrance Fees	5 0 0	
Advance Payments	3 5 0	
		140 5 0
Commission on Cheques		1 3 7
Sales of Publications		125 7 4
Sales of Extra Reprints		30 4 5
Grants:		
Union Government (Annual)	400 0 0	
University of Cape Town (Millard, Walker and Stewart)	25 0 0	
Rhodes University College (Smith and Roux, Gledhill and Szendrei) ...	13 0 0	
		438 0 0
Drawn from Post Office Savings Bank ...		150 0 0
Interest:		
Rand Provident Building Society ...	12 0 0	
Good Hope Savings Bank (General) ...	12 11 6	
Good Hope Savings Bank (Life Fund)	8 1 2	
Post Office Savings Bank	30 2 0	
Standard Bank Savings Bank	0 3 1	
Marloth Memorial Fund:		
Rand Provident Building Society	3 0 0	
United Building Society	3 0 0	
		68 17 9
		£1016 2 5

CR.

	£ s. d.	£ s. d.
Publications:		
Neill, Vol. XXX, Parts 3 and 4:		
Printing	469 1 3	
Extra Reprints	32 9 9	
Postages and Charges	16 9 8	
Galvin and Sales:		
Wicht Report	178 14 0	
		696 14 8
Local Printing		51 0 6
Clerical Assistance		49 0 0
Commission and Bank Charges		3 6 10
Petty Cash		15 0 0
Rent and Caretaker:		
University of Cape Town (Library) ...	36 0 0	
South African Association (Rent) ...	4 4 0	
South African Association (Caretaker)	2 2 0	
		42 6 0
Insurance (Library)		0 18 0
Miscellaneous:		
Editorial Expenses	7 0 0	
Typing Wicht Report	4 5 0	
Stationery	4 5 9	
Wreath (Dr. Juritz)	2 2 0	
		17 12 9
Interest credited to Accounts:		
Post Office Savings Bank	30 2 0	
Good Hope Savings Bank (General) ...	12 11 6	
Good Hope Savings Bank (Life)	8 1 2	
Standard Bank Savings Bank	0 3 1	
		50 17 9
Bank Balance at January 1, 1946		89 5 11
		£1016 2 5

R. S. ADAMSON, } Hon. Auditors.
W. PUGH, }

R. W. JAMES, Hon. Treasurer.

ASSETS AND LIABILITIES AT DECEMBER 31, 1945.

Assets.*

	£	s.	d.	£	s.	d.
Current Account Balance				89	5	11
Post Office Savings Bank				1159	4	2
Standard Bank Savings Bank				8	4	2
Cape of Good Hope Savings Bank (General Fund)				400	5	8
Cape of Good Hope Savings Bank (Life Fund)				256	16	8
Rand Provident Building Society (Fixed Deposit)				400	0	0
Arrears of Subscriptions (1944–45)				65	0	0
Marloth Memorial Fund:						
Rand Provident Fixed Deposit	100	0	0			
United Building Society Fixed Deposit	100	0	0			
				200	0	0
				£2578	16	7

Liabilities.

	£	s.	d.	£	s.	d.
Life Fund				620	14	1
Neill:						
Vol. XXXI, Part 1 (account outstanding)	250	0	0			
Material in Printer's Hands (estimate) ...	550	0	0			
				800	0	0
Allocation for Binding				350	0	0
Advance Subscriptions				3	5	0
Marloth Memorial Fund:						
Capital	200	0	0			
Interest (1942)	6	10	0			
Interest (1943)	7	0	0			
Interest (1944)	6	0	0			
Interest (1945)	6	0	0			
				225	10	0
Excess of Assets over Liabilities				579	7	6
				£2578	16	7

* Exclusive of value of Library and Publications of the Society held in stock.

R. W. JAMES, Hon. Treasurer.

We hereby certify that we have examined the above Accounts of Revenue and Expenditure, and of Assets and Liabilities, that we have compared them with the Books, Vouchers, and other Documents relative thereto, and that, in our opinion, these accounts set forth a correct description of the affairs of the Society.

R. S. ADAMSON, } Hon. Auditors.
W. PUGH, }

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR JANUARY 1 TO DECEMBER 31, 1946.

DR.	£ s. d.	£ s. d.
Bank Balance at January 1, 1946		89 5 11
Subscriptions:		
Up to 1944	13 0 0	
1945	17 0 0	
1946 (Fellows)	36 0 0	
1946 (Members)	81 0 0	
1946 (Life Subscriptions)	107 10 0	
1946 (Entrance Fees)	23 0 0	
Advance Payments	7 5 0	284 15 0
Commission on Cheques		1 4 3
Sales of Publications		94 18 5
Sales of Extra Reprints		12 13 1
Grants:		
Union Government (Annual)	400 0 0	
Mrs. A. E. F. Selfe (publication)	5 0 0	405 0 0
Drawn from Post Office Savings Bank ...		150 0 0
Interest:		
Rand Provident Building Society ...	12 0 0	
Good Hope Savings Bank (General) ...	12 0 0	
Good Hope Savings Bank (Life)	7 13 7	
Post Office Savings Bank	29 12 0	
Standard Bank Savings Bank	0 2 4	
Marloth Memorial Fund:		
Rand Provident Building Society	3 0 0	
United Building Society	3 0 0	67 7 11
		£1105 4 7

CR.	£ s. d.	£ s. d.
Neill, Vol. XXX, 1 and 2:		
Printing	439 15 10	
Extra Reprints	23 16 3	
Postage and Cost of Drafts	15 13 3	479 5 4
Local Printing		50 16 6
Clerical Assistance		48 0 0
Commission and Bank Charges		3 12 5
Petty Cash		30 0 0
Rent and Caretaker:		
University of Cape Town (Library) ...	36 0 0	
South African Association (Rent) ...	4 4 0	
South African Association (Caretaker)	2 2 0	42 6 0
Insurance (Library)		0 18 0
Miscellaneous:		
Freight and Insurance (Binding)	8 16 4	
Wreath (Dr. Rogers)	1 5 0	10 1 4
Interest credited to Accounts:		
Post Office Savings Bank	29 12 0	
Good Hope Savings Bank (General) ...	12 0 0	
Good Hope Savings Bank (Life)	7 13 7	
Standard Bank Savings Bank	0 2 4	49 7 11
Bank Balance at January 1, 1947		390 17 1
		£1105 4 7

W. PUGH,
M. R. LEVYNS, } Hon. Auditors.

R. W. JAMES, Hon. Treasurer.

ASSETS AND LIABILITIES AT DECEMBER 31, 1946.

Assets.*	£ s. d.	£ s. d.
Current Account Balance		390 17 1
Post Office Savings Bank		1038 16 2
Standard Bank Savings Bank		8 6 6
Cape of Good Hope Savings Bank (General Fund)		412 5 8
Cape of Good Hope Savings Bank (Life Fund)		264 10 3
Rand Provident Building Society (Fixed Deposit)		400 0 0
Credit Balance in Neill's account		60 11 10
Marloth Memorial Fund:		
Rand Provident (Fixed Deposit)	100 0 0	
United Building Society (Fixed Deposit)	100 0 0	
		200 0 0
		£2775 7 6

Liabilities.	£ s. d.	£ s. d.
Life Fund		706 17 7
Neill:		
Material in Printers' Hands (estimated)	600 0 0	
Additional for publication	100 0 0	
		700 0 0
Allocation for Binding		450 0 0
Advance Subscriptions		7 5 0
Marloth Memorial Fund:		
Capital	200 0 0	
Interest to 1945	25 10 0	
Interest 1946	6 0 0	
	231 10 0	
Less award for 1946 (Smith and Rivett) ...	5 0 0	
		226 10 0
Excess of Assets over Liabilities		684 14 11
		£2775 7 6

* Exclusive of value of Library and Publications held in Stock.

R. W. JAMES, Hon Treasurer.

We hereby certify that we have examined the above Accounts of Revenue and Expenditure, and of Assets and Liabilities, that we have compared them with the Books, Vouchers, and other Documents relative thereto, and that, in our opinion, these accounts set forth a correct description of the affairs of the Society.

W. PUGH,
M. R. LEVYNS, Hon. Auditors.

OBITUARY NOTICES.

ALEXANDER BROWN.

Professor Alexander Brown did great service to the Royal Society of South Africa. For years a member of the S.A. Philosophical Society and the Royal Society of South Africa, he was elected a Fellow in 1918, and was a Member of Council for the years 1931 to 1935 inclusive and again in 1941. He was Hon. Treasurer for the years 1936 to 1940, and was elected President in 1942. He continued as President till the end of 1945, with great acceptance to the Society.

While Treasurer, he introduced the method used for calculating Life Subscriptions, for a Fellow £25, as in the old rule, but lessened by one-half of the total subscriptions paid previously by him with a minimum of £10, and for a Member £15, less half of the subscriptions paid previously with a minimum of £5. There is no doubt but that this scheme was very successful in increasing the number of Life Fellows and Members, and helped to retain the connection with the Society of many who might otherwise have resigned.

He also contributed the following papers:—

1. "Examination of the Validity of an Approximate Solution of a Certain Velocity Equation," *Trans. S.A. Philos. Soc.*, vol. xvi, pt. 3, 1907.
2. "The Equivalent Mass of a Spring Vibrating Longitudinally," *Trans. Roy. Soc. S.A.*, vol. v, 1916, p. 565.
3. "The Arrangement of Successive Convergents in the Order of Accuracy," *Trans. Roy. Soc. S.A.*, vol. v, 1916, p. 653.
4. "The Use of a Standard Parabola for Drawing Diagrams of Bending Moment and of Shear in a Beam Uniformly Loaded," *Trans. Roy. Soc. S.A.*, vol. v, 1916, p. 659.

He also published the following papers: "Convergence of a Reversed Power-Series," *Brit. Ass. Report*, 1905, and "The Relation between the Distance of a Point from Three Vertices of a Regular Polygon," *Edin. Math. Soc.*, vol. 27, 1908–9.

Brown was born in 1878 at Edinburgh. He was at George Watson's College there from 1889 to 1893, being the mathematical medallist and gaining the Wright Bursary in 1893. From 1893 to 1897 he studied at Edinburgh University, taking the degree of M.A. with First-Class Honours

in Mathematics and Natural Philosophy in 1897, and in the same year the degree of B.Sc., with special distinction in the same subjects. At Edinburgh, besides gaining medals and prizes in these and other subjects, he was the holder of the first Heriot Bursary and the Mackay Smith Scholarship, and after his degrees he won the Vans Dunlop Scholarship, the Baxter Scholarship, and the Drummond Scholarship. In 1899 he won the Ferguson Scholarship open to graduates of the four universities in Scotland.

In 1897–1898 he was a mathematical master at Dundee High School, and in October 1898 he went to Cambridge and entered at Gonville and Caius College, gaining an exhibition there in that year and being elected a Foundation Scholar of the College for the remaining years. In 1901 he was Senior Wrangler, and in 1902 he obtained a First-Class in Part II of the Mathematical Tripos. In addition to special prizes at the College, he was awarded the Schuldham Plate as the best graduate of the year in 1902.

In February 1903 he came to Cape Town to the South African College to act for the year as Deputy Professor in Applied Mathematics and Physics to Professor Beattie, who had a year's leave of absence for the Magnetic Survey of South Africa which was being carried out by him and Professor Morrison. His work was so successful that at the end of the year the College Council decided to split the Chair, to offer Beattie the Professorship of Physics and to invite Brown to remain on in Cape Town as Professor of Applied Mathematics. He accepted the invitation, and was Professor of Applied Mathematics, first at the South African College and later at the University of Cape Town, till his death on January 27, 1947.

He was an excellent lecturer, and held always the attention of a class from the days of a class of fifty about 1911 to the present-day class of about two hundred. He was always accessible to the ordinary students and ready to give up his time to advising them in their difficulties. In the days before the University of Cape Town he was a regular examiner for the University of the Cape of Good Hope, and excelled in that work.

His death robs the University of Cape Town of one whose services in administrative work were outstanding. In the days of the South African College he was a member of many committees, he took part in the struggle for a separate university for Cape Town, he was Vice-Chairman of Senate from 1912 to 1914, and sat for the years 1908–1910 on the Council as Senate Assessor. His abilities were more and more made use of by the University when it came into being; he was a Member of Council with but a short break from the beginning, and was a member of practically all its committees and many of its sub-committees. In any difficulty his clear idea of the nature of the difficulty and his sound advice proved of exceptional value.

Outside his department and his administrative work for Senate and Council of the University he was always a friend of the students; from 1907

he acted for a number of years as Treasurer of their Athletics Committee; later in University days he was Head of College House for the five years 1923–1927, and for five years from 1928 to 1932 Head of Men's Residence. In all the problems of a university residence he retained the respect of the residents, helped, I have no doubt, by his quiet sense of humour, and their friendship in later days. Those of us who are at present connected with the University deplore the loss of a real lover of and worker for the University, and a man whose friendship was specially valued. He helped Beattie and Morrison with their work in the Magnetic Survey, and assisted in writing the report for the Royal Society of London of the observations from 1898 to 1906. He was interested in seismographic work, and took over from the Royal Observatory in 1932 to the Applied Mathematics Department building a seismograph which, owing to ground difficulties, had not there proved satisfactory. This showed east and west movements, but in 1934 he got through the British Association, while on a visit to England, a second instrument to show north and south movements. Both instruments were then fixed by concrete piles independent of the building to the solid rock below. Photographic observations are recorded continuously, the photographic paper being changed every twenty-four hours. The results are sent out to nineteen seismological stations.

He was elected a Fellow of the Royal Society of Edinburgh in 1907.

In 1938 he was appointed the representative of the University on the Cape Hospital Board, and in the next year he became Chairman of the Groote Schuur Hospital Committee which deals with appointments, finance, etc. for that hospital. He gave much time to this Committee and was chairman of many of its sub-committees; his work there was recognised as of the highest value and his loss is keenly felt.

In the little leisure time he had he was a great reader, not omitting detective stories, a keen musician, enjoying vocal, instrumental, and orchestral work but, curiously enough, he had no use for opera.

He married Mary Graham, then Vice-Principal of the Good Hope Seminary for Girls, Cape Town, in 1911, and is survived by her, a daughter, and a son.

L. C.

DR. ING. MAX RINDL.

On the 5th of February 1947 there passed away quietly at his home, 1 Whites Road, Bloemfontein, after an illness stretching over about six years, Max Rindl, Professor Emeritus of Organic Chemistry at the University College of the Orange Free State. In this unobtrusive manner

came to an end the career of one of the most distinguished and best-known personalities in the South African world of science.

Max Rindl was born at Kingwilliamstown in 1883, where he received his school training at Dale College, whence, after matriculating, he proceeded for further study to the University of Berlin. His studies in Chemistry, Chemical Engineering, and Metallurgy were eventually concluded at the Königliche Technische Hochschule, Charlottenburg, Berlin, a silver medal being awarded to him on the results of the final Diploma Examination. The degree of D.Sc. in Engineering was conferred on him at this institution in 1909, on a thesis "Studien über Trinitrochlornaphthalene."

On his return to South Africa in 1909 he was immediately appointed, to the then Grey University College, as Professor of Chemistry and Geology, but was relieved of the latter subject after a year or two. With the subsequent appointment of lecturers, and later of a professor for Physical and Inorganic Chemistry, he took charge of the Department of Organic Chemistry, a post which he administered in a most able manner, until he was forced to resign his Chair at the end of 1941 as a result of his failing health. His most earnest desire, so often expressed, especially during the initial stages of his illness, namely "to be able to die in harness and in the service of Science," was therefore denied him. In view of this fact one can be thankful that during the last few years of his life he was at no time subject to severe physical pain. He was, however, to be pitied for the mental agony he probably endured during this time. Up to the very last moment his mind was always clear, agile, and alert as ever, and up to the time that his speech failed him completely, but a few months before his death, he showed an unflagging interest in Chemistry and its problems, and was prepared at all times to discuss with his colleagues material points arising from their research work.

Amongst his colleagues the memory of Max Rindl's pleasing personality and friendly disposition will live for ever. Past students of the University will think of him as a most able teacher, always prepared to furnish them with sound advice, and interested in the careers of all, and will never forget his ready wit. Amongst members of our community he will be remembered as a most entertaining public lecturer and a man of sound knowledge, vision, and judgment. For men of science his publications and researches in the field of Chemistry will for ever be a record of his devotion to the study of natural science. For research work he always seemed to find time, in spite of his manifold activities. His researches, which were connected mainly with the chemistry of Poisonous and Medicinal Plants and with the Mineral Springs of South Africa, were carried out in his spare time and to a large extent under the most difficult circumstances as far as funds, equip-

ment, and general working conditions were concerned. Yet in spite of the adverse conditions he was able to bring to a successful conclusion many of the scientific problems which occupied his attention. In recognition of these activities he was elected Vice-President of the South African Association for the Advancement of Science on several occasions, and occupied the Presidential Chair of the Chemical Section in 1917. He was President of the South African Chemical Institute in 1929–1930, and became a member of the Royal Society of South Africa in 1933. He was elected Dean of the Faculty of Science of the University of South Africa in 1934, and President of the South African Association for the Advancement of Science in 1934. He was also elected as one of the two South African representatives of the International Society of Medical Hydrology.

May these distinctions and the published record of his researches serve as a fitting monument to the memory of the life and work of our colleague and friend, Max Rindl.

P. G.

LIST OF PUBLICATIONS.

CHEMISTRY OF POISONOUS AND MEDICINAL PLANTS OF SOUTH AFRICA.

1. "On the Occurrence of Daphnin in the Arthrosolen (*Lasiosiphon polycephalus*)," Trans. Roy. Soc. S. Afr., vol. vi, pt. 4 (1917), 295.
2. "A Poisonous Alkaloid from the Overground Portions of the Transvaal Yellow Tulip," Trans. Roy. Soc. S. Afr., vol. xi (1923), 251.
3. "The Toxicity of the Fruit of *Melia azedarach* (Syringa Berries)" (in collaboration with D. G. Steyn), Trans. Roy. Soc. S. Afr., vol. xvii, pt. 4 (1929), 295.
4. "A Crystalline Alkaloid from the Bark of *Strychnos Henningsii*," S.A.J.S., vol. xxvi (1929), 50.
5. "Alkaloids of the Bark of *Strychnos Henningsii*" (second communication), Trans. Roy. Soc. S. Afr., vol. xx, pt. 1 (1931), 59.
6. "Alkaloids from the Bark of *Strychnos Henningsii*" (in collaboration with M. L. Sapiro), Trans. Roy. Soc. S. Afr., vol. xxxiii, pt. 3 (1933), 239.
7. "A Contribution to the Chemistry of the Roots of *Arctopus echinatus*" (in collaboration with T. Meyer), S.A.J.S., vol. xxix (1932), 272.
8. "A Contribution to the Chemistry of *Rauwolfia Natalensis*" (in collaboration with P. Groenewoud), Trans. Roy. Soc. S. Afr., vol. xxi, pt. 1 (1932), 55.
9. "Isolation of a Glucoside from *Gnidia polycephala* (*Januarie bossie*)," Trans. Roy. Soc. S. Afr., vol. xxi, pt. 3 (1933), 239.
10. "The Glucoside from *Gnidia polycephala*" (second communication), S.A.J.S., vol. xxx (1933), 455.
11. "The Constituents of *Nicotiana Glauca*." Doctor's thesis by M. L. Sapiro.

MINERAL SPRINGS OF SOUTH AFRICA.

1. "The Mineral Springs on the Farm Rietfontein, District Brandfort," O.F.S., S.A.J.S., July 1916.
2. "Medicinal Springs of South Africa," S.A.J.S., 1917.

3. "The Medicinal Springs of South Africa." Supplement I, S.A.J.S., 1918; Supplement II, *ibid.*, vol. xxv (1928), 116; Supplement III, *ibid.*, vol. xxviii (1931), 119; Supplement IV, *ibid.*, vol. xxix (1932), 278; Supplement V, *ibid.*, vol. xxxi (1934); Supplement VI, *ibid.*, vol. xxxiii (1936).
4. "A Survey of the Medicinal Springs of South Africa." (Compiled at the request of the Department of Census and Statistics.) Year Book of the Union of South Africa.
5. "International Standard Measurements in Hydrology and a Provisional Register of Medicinal Waters in South Africa on these Standards," S.A.J.S., vol. xxvii (1930), 213.
6. "Social Hydrology in Europe with Special Reference to Rheumatic Diseases," S.A.J.S., vol. xxvii (1930), 496.
7. "International Standard Measurements in Hydrology and a Provisional Register of Medicinal Waters in South Africa, based on these Standards" (second communication), S.A.J.S., vol. xxviii (1931), 121.

ADDRESSES.

1. "Phytochemical Research." (Presidential Address to Section B of the South African Association for the Advancement of Science, 1917.) S.A.J.S., vol. xiv (1917).
2. "The Need for the Organisation of Plant Poison Research on a National Basis." (Presidential Address to the South African Chemical Institute.) Journ. of the S.A. Chemical Institute, 1930.
3. "Medicinal Springs of South Africa." (Lecture to the Bloemfontein Branch of the S.A. Medical Association.) Quarterly Scientific Number of the S.A. Medical Journal, 1936.
4. "The Significance of the Physical Properties and of the Minor Chemical Constituents of Medicinal Waters." (Lecture at the Medical School of the University of the Witwatersrand.) Published in the "Leech."
5. "Our Medicinal Springs." (Lecture to the 26th Annual Congress of the Medical Association of South Africa.) S.A. Medical Journal, vol. iii, No. 2 (1929), 33.

PAMPHLETS.

1. "Inorganic Chemical Industries." Industries Bulletin Series, No. 25.
2. "The Manufacture of Soap and Candles." Industries Bulletin Series, No. 27.
3. "Nitric Acid and other Inorganic Chemicals." Industries Bulletin Series, No. 36.
4. "Sulphuric Acid Industry." Industries Bulletin Series, No. 31.
5. "Some Sources of Non-Drying Oils." Industries Bulletin Series, No. 76.
6. "Brochure on Medicinal Springs of South Africa," issued by the S.A. Railways and Harbours, 1928.
7. "Medicinal Springs of South Africa." Illustrated handbook issued by the S.A. Railways and Harbours, 1933.

HERMANN BOHLE, M.V.D.I., M.I.E.E.

Hermann Bohle, M.V.D.I., M.I.E.E., Fellow, was born in Germany on 4th October 1876, and was educated at the Oberrealschule, Hagen, Westphalia. He graduated with honours at the Royal Engineering College, Hagen.

Coming to England, he was employed at various important engineering works in Birmingham and Walsall. He took charge of the electrical classes at the Municipal Technical School, Birmingham, and afterwards was Chief Lecturer in Electrical Engineering at the City of Bradford Technical College.

In 1906 he became the first Professor of Electrical Engineering at the South African College, since 1918 the University of Cape Town. For the next thirty years, until his retirement at the end of 1936, Professor Bohle was actively associated with the rapid and great expansion of the School of Engineering, later the Faculty of Engineering of the University of Cape Town. In 1909 he was largely instrumental in starting evening technical classes at the South African College, out of which grew the Cape Technical College. Among his many publications are textbooks on Transformers and Illumination Engineering.

He died in Berlin in July 1943, leaving a widow, two sons, and three daughters.

WILLIAM LUTLEY SCLATER.

W. L. Sclater was born on 23rd September 1863, and was killed by enemy action in London in June 1944.

Educated at Winchester and Keble College, Oxford, where he took First-Class Honours in 1885, Sclater afterwards visited British Guiana. In 1887 he was appointed Demonstrator under Professor Adam Sedgwick at Cambridge, and later in the same year Deputy Superintendent of the Indian Museum at Calcutta. From 1891 he was Science Master at Eton College until his appointment as Director of the South African Museum in 1896. In this capacity he spent ten fruitful years, reorganising the exhibits in the then newly built Museum, widening the scope of the Museum's activities, and inaugurating its scientific publication "Annals of the South African Museum," and a series of popular standard works on the fauna of South Africa (Mammals and, in collaboration with Dr. Stark, Birds).

From 1906 to 1909 he was reorganising the Museum at Colorado College (Colorado Springs was the home of his wife's people). Returning to London

he became an honorary worker at the British Museum (Nat. Hist.), where his tall, spare figure, with monocle, became familiar to all who had occasion to visit the Bird Room. In 1931 he became Hon. Secretary of the Royal Geographical Society, and held that office until his death.

His association with the South African Philosophical Society began a month after his arrival in Cape Town, when on 29th April 1896 he was elected an Ordinary Member. His value to the Society must have been immediately apparent, because he was elected to the Council on 30th September of that same year. He continued to serve on the Council until 1904, and was Hon. Treasurer from 1897 to 1903. After the Philosophical Society became the Royal Society of South Africa he continued as a Member until 1913.

At meetings of the Society he frequently exhibited objects of interest, including the photograph of a skull of a Giant Lemur from Madagascar, stating that for the actual skull the extraordinary price of £8500 (*sic.* Min. Proc. S. Afr. Phil. Soc., 12th July 1899) was asked.

He was one of a Committee of five members appointed to discuss with five members of the Cape Photographic Society the formation of a collection of standard-sized photographs as permanent records of Bushman paintings. The Society's Minutes of Proceedings do not record the outcome of this valuable suggestion.

In 1899 Sclater's father, P. L. Sclater (Secretary of the Zoological Society, London), addressed the Society on the desirability of forming a Zoological Gardens in Cape Town. But although the Council was instructed to discuss the question of forming a Cape Zoological Society, the matter seems to have dropped.

Sclater's most important contributions to the Society's Transactions were three papers on the Diaz Cross and Post Office and other inscribed stones, published in 1898, 1901, and 1906, which focused attention on these historical Cape records. In his work on Mammals and Birds the historical background was as carefully recorded as the current literature on the subject.

The present writer only met Sclater on two brief occasions at the British Museum, but from all accounts he had a most engaging personality, and was always ready to help the earnest student from his vast store of information.

The above biography has been culled from the Proceedings and Transactions of the S.A. Philosophical Society, and Obituary Notices in Nature (vol. 154, 12th August and 23rd September 1944), and S.A. Mus. Assoc. Bull. (vol. 3, September 1944).

K. H. B.

JOHN TODD MORRISON.

John Morrison, who died at Stellenbosch on October 24, 1944, at the age of eighty-two, came to South Africa in 1892 to a Professorship at the Victoria College, Stellenbosch. When the College became the University of Stellenbosch in 1918, he became the first Professor of Physics there and held that Chair until he retired in 1934.

Morrison came to the University of Edinburgh from Watson's College, where he passed out dux. At the University he had a brilliant career and obtained the degrees of M.A. and B.Sc. During his life in Edinburgh he made many friends, and had interesting contacts with men such as Robert Louis Stevenson, Barrie and others. He began his teaching career there at the Heriot Watt College. His alert mind, his sympathetic and courteous manner established him as a successful teacher, one who appealed to Scottish and South African students alike.

Morrison took a great interest in the development of university education in South Africa. The old University of the Cape of Good Hope, modelled on the University of London, did much to raise the standard of examinations in South Africa. He was for many years a Member of the Council of that University, and contributed greatly to the raising of the standard of work in his own subject and in the work of the University generally. His counsel was often sought and was readily given, while his alertness and sympathy often helped his colleagues to harmonious and fruitful decisions.

He interested himself in local affairs as well. His work and influence in that side of his life is best known by what he did in obtaining a hospital for Stellenbosch. Few know how much time he gave before he finally succeeded in getting first the building and later its equipment.

In research he was keenly interested. His first paper, in collaboration with H. R. Mill, was published in 1886; his last, in the Phil. Mag., in 1937. A few days before his death he was still working at a paper on "The Circulation of the Atmosphere," which unfortunately he did not live to complete.

The work with which his name will always be associated is the first Magnetic Survey of South Africa. It had been pointed out that the data for the study of earth magnetism was incomplete in the Southern Hemisphere. Many physicists had urged the need of observations, particularly in Africa. To mention only two—van Ryckevorsel in Holland in the 'eighties of last century had urged the desirability of filling in this gap in our magnetic knowledge; Bauer, of the Department of Terrestrial Magnetism of the Carnegie Institution, Washington, also pointed out the necessity for magnetic work here.

The beginning was made in the Christmas vacation, 1897–98, when

Morrison and the writer made observations at various points on the railway line between Cape Town and Bulawayo. After that Morrison spent most of his vacations during the next ten years in field operations, and in 1909 took a year's leave, a year spent entirely in magnetic work at stations distributed between Cape Town and Cairo. The labour he performed was a great contribution to a first magnetic survey of Africa and more particularly of South Africa.

He was a Fellow of this Society and of the Royal Society of Edinburgh, and an Honorary D.Sc. of the University of Cape Town.

J. C. B.

ARTHUR W. ROGERS, Sc.D., F.R.S.

The President expressed the regret of the Society at the death of Dr. A. W. Rogers, one time President of this Society.

Arthur W. Rogers was born in Somersetshire on June 5, 1872, and graduated with honours from Christ's College, Cambridge.

Appointed Assistant Geologist to the Geological Commission of the Cape of Good Hope, Cape Town, in 1896, he later became its chief, and Director of the Geological Survey of the Union, Pretoria, from 1916 to 1932. Associated with the late Professor E. H. L. Schwarz during those early years, he carried out extensive surveys of little known parts of the Cape Province, particularly in the north and north-west, as far as the borders of the Kalahari, making many novel geological and geographical discoveries. In the Transvaal his chief work, apart from administrative duties, lay in the detailed mapping of the Heidelberg and Klerksdorp goldfields.

During his directorship the reputation of the Geological Survey reached a high standard, and a general stimulus was given by the visit of the International Geological Congress in 1929. For such steadfast lead over so lengthy a period, geology in this land is under no small obligation.

Of his numerous and illuminating writings, official reports and addresses —essentially on geological, physiographical or climatic problems—must ever stand out his intriguing history of "The Pioneers in South African Geology and their Work," published by the Geological Society of South Africa in 1937.

Dr. Rogers will always be remembered as a modest scientist of happy disposition, high principles and repute, ever ready to do justice to the work or opinions of others. To scientific bodies his extensive experience proved particularly valuable. He was a Fellow of the Royal Society of London, President of this Society during 1934–35 (the occasion of two far-reaching

addresses on the Kalahari Region), of the Geological Society of South Africa, the South African Association for the Advancement of Science, and the International Geological Congress in 1929. He was furthermore the recipient of the Bigsby, Wollaston, South Africa, Scott and Draper Medals, and of an Honorary D.Sc. degree from the University of Cape Town and that of the Witwatersrand.

Retiring in 1932 to Mowbray, he devoted himself mostly to microscopical and microchemical investigations, the more so after his crippling illness of 1938. No longer able to travel freely, he found solace in his fine library. By good fortune a unique account of the Diatom Floras of the Diatomite Deposits of South Africa was completed shortly before his decease at Mowbray on June 23, 1946.